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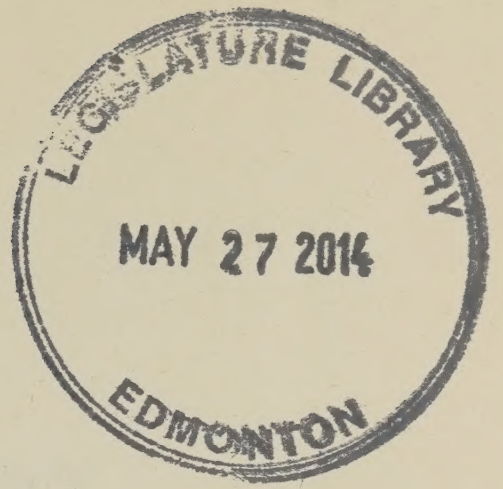
ELEVENTH
ANNUAL REPORT
OF THE
RESEARCH COUNCIL
OF ALBERTA
1930

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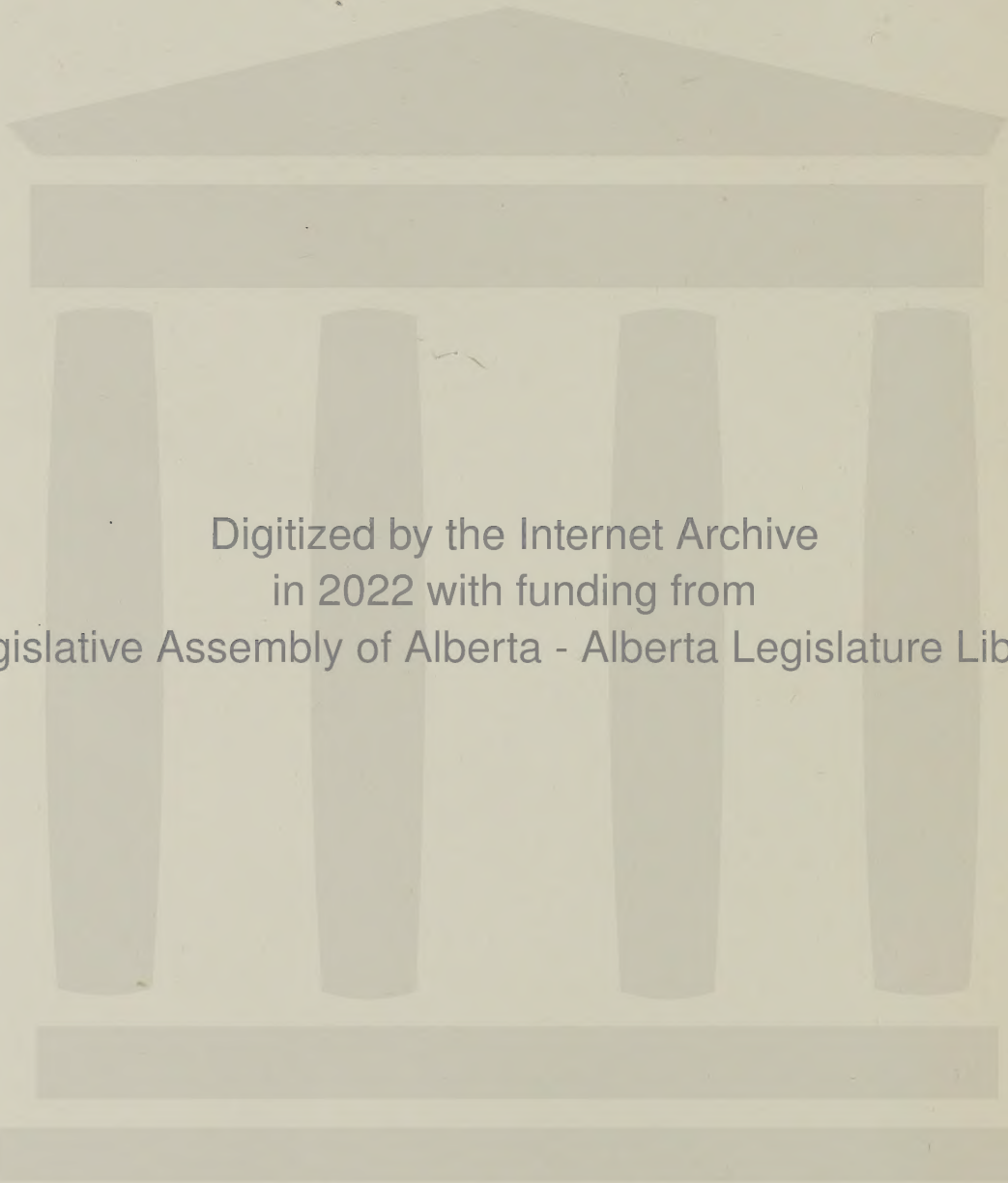


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1931

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The Research Council of Alberta, formerly known as The Scientific and Industrial Research Council of Alberta, was formed in January, 1921. It was incorporated under its new name by an act of the Legislature of the Province of Alberta March 21st, 1930.

The personnel of the Council at the present time is as follows:

J. E. Brownlee, Premier of Alberta, Chairman.
R. G. Reid, Minister of Lands and Mines.
O. L. McPherson, Minister of Public Works.
R. C. Wallace, President, University of Alberta, Director of Research.
R. S. L. Wilson, Dean, Faculty of Applied Science, University of Alberta.
G. A. Vissac, Esq., Blairmore.
J. I. McFarlane, Esq., Calgary.
R. J. Dinning, Esq., Edmonton.
Secretary, A. E. Cameron, University of Alberta.

Technical Advisors (meeting with Council)

Prof. J. A. Allan—Geology.
Prof. N. C. Pitcher—Mining Engineering.
Prof. E. Stansfield—Chemical Engineering.

The Council carries on its work in cooperation with the University of Alberta where its laboratories are situated. Requests for information and reports should be addressed to the Secretary, Research Council of Alberta, University of Alberta, Edmonton, Canada.

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UNIVERSITY OF ALBERTA,

EDMONTON, CANADA,

FEBRUARY 7TH, 1931.

HON. J. E. BROWNLEE,

Premier,

Edmonton, Alberta.

SIR:

Under instruction from the Research Council of Alberta, I herewith submit their Eleventh Annual Report. This covers the work done under their direction during the year ending December 31st, 1930.

Respectfully submitted,

R. C. WALLACE,

Director of Research.

ELEVENTH ANNUAL REPORT OF THE RESEARCH COUNCIL OF ALBERTA

ORGANIZATION

In the organization of the Provincial Government the Research Council is attached to the Department of the Executive Council.

The Research Council controls the policies of research and administers the funds voted annually by the Legislature for this purpose. The Council usually meets three or four times a year. The Director of Research, Dr. R. C. Wallace, President of the University of Alberta, is in executive charge of the work and is assisted by a technical advisory committee consisting of the following members:

PRESIDENT R. C. WALLACE, Chairman.
DEAN R. S. L. WILSON, Vice-Chairman.
J. A. ALLAN.
N. C. PITCHER.
E. STANSFIELD.
K. A. CLARK.
F. A. WYATT.
E. H. BOOMER.
R. L. RUTHERFORD.
H. J. MACLEOD.
A. E. CAMERON, Secretary.

The offices and laboratories of the Council are situated in the buildings of the University of Alberta.

STAFF

The permanent staff of the Council as of December 31st, 1930, was as follows:

Edgar Stansfield, Chief Chemical Engineer;
K. A. Clark, Research Engineer, *Road Materials*;
R. L. Rutherford, Geologist, *Geology*;
W. A. Lang, Engineer, *Fuels*;
D. S. Pasternack, Engineer, *Road Materials*;
K. C. Gilbart, Assistant Engineer, *Fuels*;
R. G. Brewer, Assistant Engineer, *Fuels*;
M. F. Teskey, Fuel Analyst, *Fuels*;
J. L. Doughty, Research Assistant, *Soils*;
O. R. Younge, Research Assistant, *Soils*;
A. W. Saddington, Research Assistant, *Natural Gas*;
P. E. Gishler, Research Assistant, *Natural Gas*;
H. E. Morris, Research Assistant, *Natural Gas*;
Frank J. Hastie, Laboratory Assistant, *Fuels*;
Robert M. Scott, Laboratory Assistant, *Road Materials*;
Hazel M. Wortman, Accountant;
Mary Sandin, Geological Stenographer;
Alta Jackson, Stenographer.

In addition to the above, Professors J. A. Allan and N. C. Pitcher, of the University of Alberta, are in permanent charge of the Council's research work in Geology and Mining Engineering respectively. Professor F. A. Wyatt is in charge of the Council's work on Soil Surveying. Dr. E. H. Boomer has carried out natural gas and hydrogenation investigations. Dr. A. E. Cameron acts as secretary to the Council and has charge of the office staff. R. G. Reiber, on the staff of the Industrial Laboratories of the University, worked part time as a graduate student up to May 1st.

LABORATORIES AND EQUIPMENT

The principal items of laboratory equipment acquired during the year is as follows: purchased, Graham apparatus for the determination of carbon-monoxide, multiple unit muffle furnace, cathetometer, dew point hygrometer, automatic recording balance, platinum Gooch crucible; designed and constructed, cabinet for storage of maps and drawings, viscosimeter, mercury hoist for gas analysis apparatus.

FUELS

The main work of the year was a detailed examination of thirteen typical coals occurring in the south of the Province. As this is the first occasion on which such a coal survey has been made in this Province the work involved not only the actual tests but also a lot of preliminary investigations such as the development of new tests and improvement in old ones. This work, which was done with the co-operation and assistance of the Dominion Department of Mines, The Provincial Mines Branch, and the National Research Council, was of the nature of a preliminary study to ascertain the value and cost of such a survey if carried out over a wider area. This investigation is not yet completed, but the results to date, which are tabulated in the attached report of the Fuels Division, show very clearly the wide range of coals which are available within a comparatively small area. Thus the calorific values of the coals as mined ranged from 14,500 B.t.u. to 7,000 B.t.u. per lb. and the fixed carbon in the pure coal substance, with moisture as mined, ranged from 88% to 36%.

A comparative study of the outputs of run-of-mine and slack coal from four Edmonton area mines was commenced during the year. The same samples were also used to continue an investigation on sample storage and air drying of coal.

The samples tested during the year amounted to 66 in addition to the many samples received for the coal survey. Samples have now been received and tested from 300 mines in the Province. The regular testing programme was continued and amplified in many directions. An unusually large number of ultimate analyses and determinations of calorific value were made during the year. Two new indices were devised for evaluating the physical character of a coal, termed storage index and strength index respectively. These are based on the slacking test developed at Pittsburgh and on a friability test developed in these laboratories. Both are described in the report of the Fuels Division.

The coal washing investigation commenced last year was completed early in the present year, although a study of the clinkering characteristics of raw and cleaned coal is still in progress. A preliminary investigation on the solubility of coal in organic solvents was also completed, but a further and more detailed study is to be carried out. Work on the determination of solubility of coal in caustic potash made good progress during the year and it is hoped to complete and publish this work shortly.

Fuller details of the above work are given in the report of the Fuels Division. This report also includes a summary of the results of J. Iyon Graham and D. G. Skinner of Birmingham University on hydrogenation of six Alberta coals.

GEOLOGY

The work of the Geological Survey Division of the Council is carried on in conjunction with the Department of Geology at the University of Alberta, under the direction of J. A. Allan. The palaeontological material obtained on field surveys is determined by P. S. Warren, and in return for this co-operation, R. L. Rutherford assists in teaching in the Department of Geology. After the field season, H. S. Hicks left for the University of Minnesota, where he is continuing further study on the Precambrian rocks from the northeastern part of Alberta.

Report No. 21, "Geology and Water Resources in Parts of the Peace River and Grande Prairie Districts, Alberta," by R. L. Rutherford, with geological map, was published during the year.

Three field parties carried on geological investigations for varying periods during the season. One party, under the direction of R. L. Rutherford, carried on field surveys in districts of the Peace River adjacent to those examined in 1929. The object of this was to obtain geological information relative to the water supply in those districts. A party under the direction of A. E. Cameron continued field investigations in the Precambrian area in the northeast corner of Alberta, north of Lake Athabasca. J. A. Allan, in company with Dr. Wallace and Dean Wilson, made a trip by airplane from Cooking lake to Fitzgerald and visited the Cameron-Hicks party in this area. A week was spent by R. L. Rutherford and P. S. Warren continuing investigations in the Jasper park area. J. A. Allan examined a reported occurrence of talc west of Banff, south of Castle. R. L. Rutherford carried on preliminary investigations in part of the area between Ft. Assiniboine, Athabaska Landing and Cold Lake, Alberta. Compilation of water well data was continued during 1930, and records of over 400 wells were obtained by J. Tatham in September.

Details of this work are given in the attached report of the Geological Survey Division.

ROAD MATERIALS

The Road Materials Division completed the work assigned to it in the two year plan of co-operative bituminous sand studies by the Federal Department of Mines and the Research Council of Alberta.

The erection of a separation plant beside the bituminous sand quarry of the Department of Mines on the Clearwater river was finished and the plant was operated during the summer. Bituminous sand separation at the deposits in the north country was given practical demonstration and further information was gained about plant design and operation and separation procedure. Approximately fifteen thousand gallons of separated bitumen were produced. The bitumen was shipped to Edmonton and was used by the Federal Department of Mines and the Public Works Department of the Province of Alberta for pavement and rural road experiments.

Separation plant operation and associated laboratory studies are discussed in detail in the attached report of the Road Materials Division.

SOIL SURVEYS

At the request of the Provincial Government the Research Council during 1930 undertook the general supervision of extensive soil surveys in the northern portions of the Province. Three field survey parties were in the field for the greater part of the field season. The work was directed for the Council by Dr. F. A. Wyatt, Professor of Soils at the University of Alberta. J. L. Doughty, with A. D. Paul as assistant, examined the area extending from Peace River to Fort Vermilion on the east side of the Peace river. O. R. Younge, with N. Holowaychuk as assistant, examined the area between Keg River post, Fort Vermilion and Hay River post. A. S. Ward, with H. J. Mather as assistant, examined the area between High Prairie and Bezanson.

Preliminary reports covering the results of these field surveys appear in the attached reports of the Soils Survey Division.

CHEMICAL UTILIZATION OF NATURAL GAS

The studies on the chemical utilization of Alberta natural gas were confined to three principal divisions; the hydrogenation of McMurray bitumen at high pressures and temperatures, the reactions of water gas and carbon dioxide-hydrogen mixtures at high pressures and temperatures and the pyrolysis of natural gas. The second division, on the reactions of water gas, includes an extensive examination of the decomposition of ethyl alcohol over a wide variety of catalysts. The progress in the hydrogenation and pyrolysis divisions was encouraging and shows distinctly practical results. The National Research Council of Canada continued its co-operation and defrayed half the expenses of the investigation.

A brief report summarizing the laboratory studies appears in the attached report on Natural Gas Research.

MISCELLANEOUS

E. Stansfield attended the annual meeting of the Canadian Institute of Mining and Metallurgy and a National Research Committee meeting on Coal Classification and methods of analysis at

Toronto in March. He also attended the Canadian Chemists Convention and a meeting of the National Research Council's Gas Research Committee in Ottawa in May. He presented a paper on fuels to the Canadian Chemists Convention.

Dr. Wallace and other members of the staff conferred, in September, with the Director of the Federal Mines Branch relative to next year's programme of work. E. Stansfield subsequently conferred at Ottawa with the staff of the Fuel Testing Division. On his return he visited mines in the Crow's Nest Pass from Blairmore to Lundbreck, and also the power plant at Sentinal.

J. A. Allan and A. E. Cameron, in September, attended the Annual Western Meeting of the Canadian Institute of Mining and Metallurgy at The Pas, Flin Flon and Sherritt Gordon.

Two sterilization indicators, said to be the Diack and the Teller, have been tested at the request of Dr. R. T. Washburn, Superintendent of the University Hospital. Under the conditions of the test the tubes said to be "Diack" changed color at temperatures of 243-248°F, and the tubes said to be "Teller" read "Sterile" at temperatures of 234-238°F.

ACKNOWLEDGMENTS

Appreciation is expressed to Coal Operators of the Province for coal samples supplied by request; and to G. A. Vissac, General Manager, West Canadian Collieries, for hospitality and assistance to E. Stansfield during his visit to the Crow's Nest Pass district.

Thanks are also due to The Fuels Division of the Dominion Mines Branch and also the Provincial Mines Branch for co-operation and assistance with the collection of coal samples for a Coal Survey across the south of the Province; and to the National Research Council for financial assistance in the same work.

The Soil Survey Division wishes to express its appreciation of the assistance rendered by the Dominion Department of Interior, Topographical Survey Branch, in connection with supplying of base maps used for field work, together with subdivision surveys in areas recommended for settlement.

PUBLICATIONS DURING 1930

Report No. 21, Geology and Water Resources in Parts of Peace River and Grande Prairie Districts, by R. L. Rutherford.

Report No. 25, Annual Report of Council covering the work done in 1929.

"Mineral Development in Alberta in Past Ten Years," by J. A. Allan. Monetary Times, Vol. 86, p. 226, Jan. 9, 1931.

Report No. 23, Preliminary Soil Survey Adjacent to the Peace River, Alberta, West of Dunvegan, by F. A. Wyatt and O. R. Younge.

"Determination of Mineral Matter in Coal and Fractionation Studies of Coal," by E. Stansfield and J. W. Sutherland, A.I.M.M.E., February, 1930.

News Letter to Coal Operators of Province, No. 4, March, 1930.

"Yardsticks for Fuels," E. Stansfield, Canadian Chemists Convention, May, 1930.

"On the Hydrogenation of Bitumen from the Bituminous Sands of Alberta," by E. H. Boomer and A. W. Saddington, Canadian Journal of Research, June, 1930.

"The Formation of Ethane in the Catalytic Decomposition of Ethyl Alcohol," by E. H. Boomer and H. E. Morris, Canadian Journal of Research, June, 1930.

"The Determination of Carbon and Hydrogen," E. Stansfield and J. W. Sutherland, Canadian Journal of Research, October, 1930.

News Letter to Coal Operators of Province, No. 5, October, 1930.

"Oxygen Bomb Calorimeter," E. Stansfield and J. W. Sutherland, Canadian Journal of Research, November, 1930.

"Experimentation with Bituminous Sand," K. A. Clark, World Petroleum, September, 1930.

Geology of Ste. Anne Sheet. J. A. Allan, Appendix to Soil Report by F. A. Wyatt, Bulletin No. 20, Dept. of Agriculture, University of Alberta.

FUELS DIVISION

BY E. STANSFIELD, W. A. LANG, K. C. GILBART, R. G. BREWER
AND M. F. TESKEY

All members of the staff worked during part of the year on the coal survey referred to below, and on problems arising therefrom. The remainder of their time was separately divided between the different items referred to later. J. W. Sutherland assisted from May to September inclusive with the coal survey, his salary being paid by the National Research Council.

COALS TESTED

Provincial Mine Inspectors submitted 12 channel samples of coal for analysis and 3 samples of seam roof for special investigation. Coal for investigation was obtained from 13 mines in connection with a special survey; one five gallon can sample and 12 quart sealer samples were taken from each mine. Other samples were taken at the same time and shipped to Ottawa for supplementary tests. Coal operators submitted 14 samples for special investigation. These included one sample of coal weighing about 7 tons; 7 small coal samples, 5 samples of washery refuse and one barrel of briquettes. Ten samples of coal were kindly supplied by the Fuel Testing Laboratories at Ottawa for special work on sulphur in coal. The staff of the Division collected 24 samples representative of the run-of-mine and slack outputs of four local mines. Six miscellaneous samples were also received. Samples were received during the year from 7 mines not previously sampled and coal from some 300 mines has now been analysed.

SAMPLING AND ANALYSIS

No notable change has been made during the year in the regular methods of sampling and analysis. Some of the coal survey samples were shipped, and stored for analysis, under water, the water being removed by centrifuging prior to air drying; this method involves additional work and was not found to be entirely satisfactory. Tests are now in progress on a method of storing under slightly reduced pressure, and so far the results have been encouraging. The present method of air drying coal samples has been shown to be not entirely independent of laboratory temperature, and also to involve slight oxidation of low rank coals; a new method is being developed. Improvements have been made in the determination of solubility of coal in caustic potash (ulmic constituents), and in the method of expressing the results of weathering tests; whilst a test has been devised for evaluating the friability of coal. In the test for solubility in potash, which it is proposed to publish shortly, the dissolved material can be reprecipitated and weighed.

SOUTHERN ALBERTA COAL SURVEY

At a conference held in Edmonton in October, 1929, and attended by representatives of the National Research Council and the Dominion Department of Mines, it was suggested that a coal survey should be made, over a limited area in Alberta, to ascertain the value and also the cost in time and money, of a thorough investigation of the nature of the coals. New methods for the utilization of coal have been developed in the last few years and more methods are in process of development. The old simple methods of analysis are no longer sufficient to evaluate and classify coals. The 1930 survey was intended as a preliminary study of a number of typical coals by old and new methods of analysis in order to ascertain the probable value of such a survey and the practicability of extending it to other parts of Alberta and to the rest of the Dominion.

An important feature of this investigation was a study of the composition and nature of the pure coal substance from each mine, and a comparative study of the different types represented. The investigation also included a study of the physical properties of the coals as mined. The work was not planned to ascertain the normal percentage of impurity in the commercial grades of the coals.

Each sample of coal was divided into five or more fractions with different ash percentages, and a complete proximate, ultimate and calorific value analysis made of each fraction. The results for each constituent were plotted against the corresponding ash percentage, and, from the resulting curves it was possible to deduce the correct and full analysis of the pure coal substance. These analyses of the pure coal are given in the following table, together with the results of a number of physical tests. The coals, marked A to N, are arranged in order of descending fixed carbon content in the coal, moist as mined. It will be noted that, excluding mines within the mountains, this is also the order of increasing distance of the mines from the mountain face. It might be noted also that coal H, which is of more recent geological age than the adjacent coals, falls smoothly into the series with respect to ordinary analyses, but gives distinctly anomalous results with such tests as solubility in caustic potash.

Hydrogenation tests and determinations of solubility in organic solvents are yet to be carried out. It is expected that these results will emphasise the value of the other methods of studying the character of the coals. The carbonisation tests also are not yet completed.

The Department of Mines at Ottawa is co-operating in this work and sent a member of their staff, Mr. G. P. Connell, to take the samples. They have made some carbonisation tests and expect to make micro-examinations, etc. The Provincial Mines Branch also gave valuable assistance in the collection of the samples, which were all taken under the personal supervision of Mr. J. B. de Hart.

TABLE I.
COAL SURVEY—TYPICAL SOUTHERN ALBERTA COALS

Coal	A K	B K	C K	D K	E K	F B	G B	H E	J B	K B	L B	M B	N E
Geological horizon1	.....	.....	.....	.....	4	6	60	60	92	110	135	155	157
Approximate distance of mine east of mountain face—miles	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Proximate analysis of pure coal, moist as mined:	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Fixed carbon	87.5	84.0	68.2	62.4	58.7	54.2	52.0	51.2	48.9	45.5	43.4	41.3	36.2
Volatile matter	10.3	14.6	30.4	36.4	37.8	40.9	38.2	34.5	34.9	33.0	31.8	30.7	31.8
Moisture	2.2	1.4	1.4	1.2	3.5	4.9	9.8	14.3	16.2	21.5	24.8	28.0	32.0
Proximate analysis of pure dry coal:	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Fixed carbon	89.5	85.2	69.2	63.2	60.8	57.0	57.7	59.8	58.4	58.0	57.7	57.4	53.3
Volatile matter	10.5	14.8	30.8	36.8	39.2	43.0	42.3	40.2	41.6	42.0	42.3	42.6	46.7
Ultimate analysis of pure coal, moist as mined:	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Carbon	90.42	89.38	87.07	86.21	81.73	79.22	71.34	67.40	64.86	60.21	56.33	52.62	48.72
Hydrogen	4.15	4.45	5.24	5.66	5.75	6.25	5.92	6.13	6.12	6.40	6.66	6.83	7.06
Oxygen	3.52	3.70	5.97	6.21	10.93	11.77	20.53	25.06	26.80	31.19	35.43	39.36	43.20
Nitrogen	1.27	1.68	1.28	1.48	1.16	2.19	1.71	1.11	1.68	1.49	1.05	0.79	0.75
Sulphur	0.64	0.79	0.44	0.44	0.43	0.57	0.50	0.30	0.54	0.71	0.53	0.40	0.27
Ultimate analysis, pure dry coal:	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Carbon	92.45	90.65	88.30	87.25	84.70	83.30	79.10	78.65	77.40	76.70	74.90	73.10	71.65
Hydrogen	4.00	4.35	5.15	5.60	5.55	6.00	5.35	5.30	5.15	5.10	5.20	5.15	5.15
Oxygen	1.60	2.50	4.80	5.20	8.10	7.80	13.10	14.40	14.80	15.40	17.80	20.10	21.70
Nitrogen	1.30	1.70	1.30	1.50	1.20	2.30	1.90	1.30	2.00	1.90	1.40	1.10	1.10
Sulphur	0.65	0.80	0.45	0.45	0.45	0.60	0.55	0.35	0.65	0.90	0.70	0.55	0.40
Calorific value of pure coal, Moist, B.t.u. per lb.....	15,380	15,560	15,380	15,490	14,620	14,240	12,580	11,880	11,320	10,370	9,940	9,250	8,417
Dry, B.t.u. per lb.....	15,730	15,780	15,600	15,680	15,140	14,970	13,950	13,860	13,510	13,210	13,220	12,850	12,380
Fuel ratio	8.5	5.8	2.25	1.70	1.55	1.35	1.35	1.50	1.40	1.40	1.35	1.35	1.15
Solubility of pure dry coal in caustic potash.....	0.0	0.0	0.0	0.0	0.2	1.9	11.4	45.0	13.4	39.5	48.8	52.6	56.1
Specific gravity of coal with 8% ash and moist as mined	1.40	1.37	1.34	1.33	1.35	1.32	1.35	1.38	1.36	1.35	1.35	1.34	1.33
Ignition temp. of dry coal	470	469	423	428	388	378	371	360	340	329	?	?	?
Storage index	96	97	90	99	96	97	90	34	51	5	3	9	3
Strength index	40	42	12	54	43	59	62	43	55	44	52	66	81
Softening temperature of ash	2,550	+2,570	2,570	+2,570	2,570	2,140	2,150	1,900	2,180	2,100	1,870	1,880	2,010

NOTE 1—K: Kootenay; B: Belly River; and E: Edmonton horizons.

The National Research Council helped financially, and made it possible to have Mr. J. W. Sutherland's assistance for more than four months in the laboratory studies.

SLACKING CHARACTER OF COAL AND STORAGE INDEX

Seventeen samples of coal were tested according to the procedure of the United States Bureau of Mines, as described in an earlier report*.

A new method has been devised for graphically representing the results and also for computing therefrom a storage index for the coal tested. The test itself is briefly as follows: A sample of fresh coal, sized to uniform small lumps, is air dried and then repeatedly subjected to the following cycle of treatments, (1) immersion under water for 1 hour, (2) air dried for 24 hours, (3) screened. The percentage weight of the original coal left is determined after each screening. A consideration of this test shows that the coal which remains unbroken after five cycles of treatment should be given more credit than that which only survives four cycles, and so on, therefore the graphical representations and computations were arranged accordingly. In the chart shown on the left of fig. 1 the percentage weight left is shown plotted against the screening number, each screening being represented by unit length on the abscissae scale. The lost material is represented by the hatched area and the unbroken coal by the clear area. The clear area expressed as a percentage of the total area is called the storage index of the coal. Arithmetically the percentages left after each screening are added together and divided by five, the number of screenings.

This test is not complete in itself as some coals suffer degradation in the slacking test merely because they are friable and break during screening. A friability test has been standardised as described below. The two tests, taken together, give a good indication of the physical character of any coal.

FRIABILITY OF COAL AND STRENGTH INDEX

A friability test for coal was developed by J. H. H. Nicoll† in 1924, in which the sample is rattled for three hours in a small jar provided with lifters. This test takes too long for a satisfactory routine test, so it has been modified in this laboratory by the use of the standard rattler machine adopted by the American Society of Testing Materials for testing paving bricks. The drum is 25 inches long and 30 inches outside diameter, and is built of cast-iron plates 6 inches wide, 25 inches long and $\frac{1}{4}$ inch apart. This rattler was fitted with one sheet iron lifter about 3" high, inserted between two of the plates. With each revolution of the drum this lifter hits the coal being tested, carries it up to the top and allows it to drop onto the iron plates below, where it rolls around till again struck by the lifter. The fine coal produced falls out through the $\frac{1}{4}$ inch gap between the plates so that the falling coal is not cushioned by dust and fines.

*Scientific and Industrial Research Council of Alberta, Annual Report for 1928, p. 16.

†Investigations of Fuels and Fuel Testing, Mines Branch, Department of Mines, Ottawa, Report No. 644, page 20.

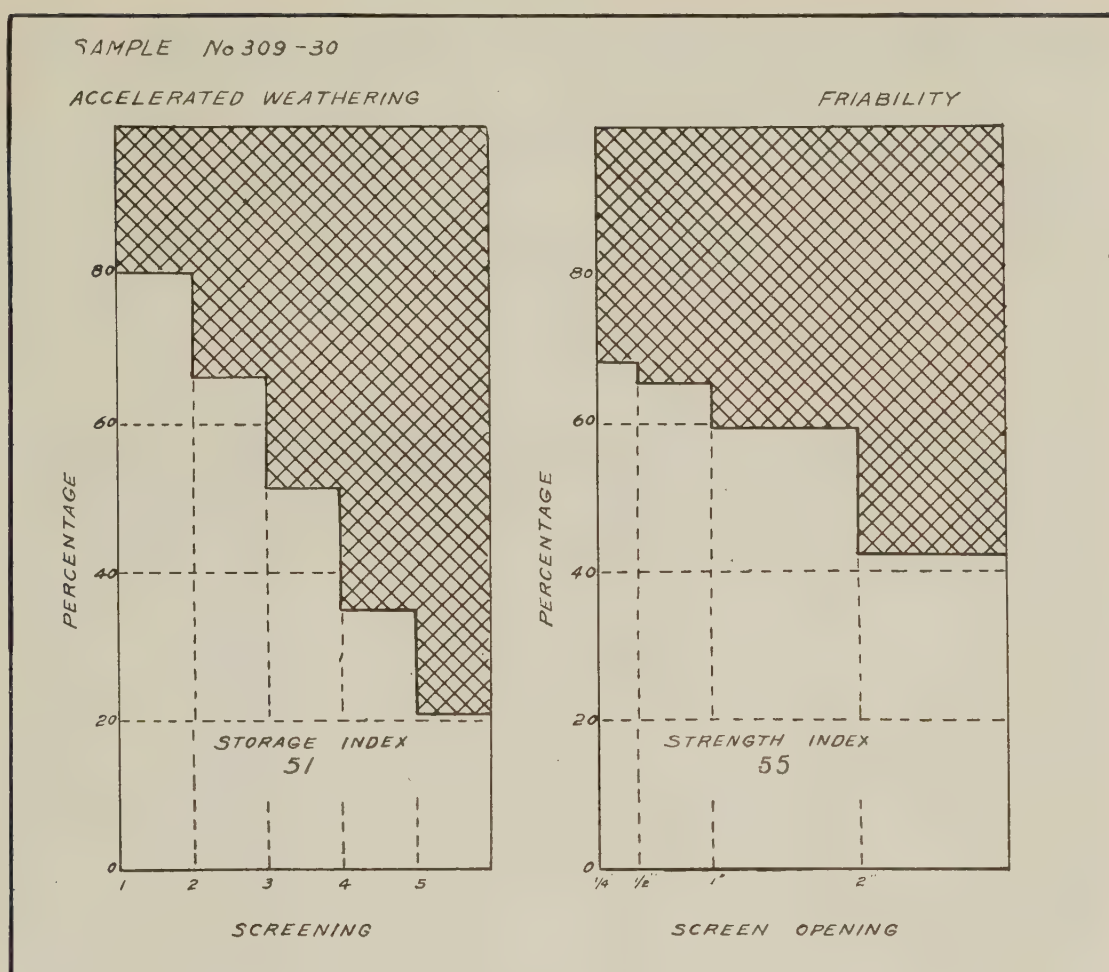


Figure 1.

In a test a 2500 gram sample of 3 inch lumps of fresh coal is rattled in the machine for exactly three minutes, the machine being driven at 32 revolutions per minute. The coal left after the test is screened through 2 inch, 1 inch, $\frac{1}{2}$ inch and $\frac{1}{4}$ inch Tyler standard screens and the weight left on each screen is recorded. The number and shape of the lumps left on the 2 inch screen are also noted. The complete test is carried out in duplicate and the results averaged.

A new feature was developed for this test as it seemed advisable to reduce the percentage weights on the screens to a single value which would represent either the friability or, conversely, the strength of the coal.

In considering the results it can be seen that more credit should be given to the stronger pieces which remain on the 2 inch screen than to those which remain on the 1 inch screen, and so on. A strength index could be computed from such a test by many methods which would give the desired emphasis to the larger pieces. The one selected is indicated graphically on the right hand side of fig. 1. Here the strength index is the clear area expressed as a percentage of the total area. The cumulative weight on each size is plotted as ordinate against the limiting size of the pieces as abscissae. That is against 3 inches to 2 inches for the pieces passing a 3 inch screen and remaining on a 2 inch screen, and so on. As the coal passing through the $\frac{1}{4}$ inch mesh is regarded as total loss in this test, the

abscissae scale commences at the $\frac{1}{4}$ " mark. The computation of the strength index can be made by multiplying the weight passing the 3 inch screen and remaining on the 2 inch by $2\frac{3}{4}$ " ($3-\frac{1}{4}$), multiplying the weight passing 2 inch and remaining on 1 inch by $1\frac{3}{4}$, multiply the weight passing the 1" and remaining on the $\frac{1}{2}$ " by $\frac{3}{4}$ and the weight passing the $\frac{1}{2}$ inch and remaining on the $\frac{1}{4}$ inch by $\frac{1}{4}$, and dividing the sum of the totals by $2\frac{3}{4}$. Or, more simply, from the cumulative percentages which would remain on each screen by adding together the full values for the 2 inch and 1 inch screens, half the value for the $\frac{1}{2}$ inch screen, and one quarter the value for the $\frac{1}{4}$ inch screen and dividing the sum by $2\frac{3}{4}$.

It seemed better in this and the slacking test to represent the perfect coal as 100, with lower values for inferior coals. That is to give values for strength and storage indices rather than friability and weathering indices.

COAL WASHING AND ASH FUSION

Coals from most of the important bituminous mines were tested, by laboratory methods, to ascertain their amenability to cleaning by commercial processes. The graphical method developed for showing the results was described in the Annual Report for 1929. This method shows for any yield of clean coal expressed as a percentage of the raw coal treated, (1) the percentage of ash in the clean coal, (2) the percentage of ash in the material discarded, (3) the loss of combustible matter in the discard, (4) the percentage of the original ash removed in the discard, and (5) the specific gravity of heavy solution on which such yield of clean coal would float. The curves obtained show that with the coals tested a distinct ash reduction could be obtained with small loss of combustible material. The point at which the cuts would be made in commercial practice, however, would depend on the product desired and upon local condition. Recoveries would depend on the product desired and upon local condition. Recoveries of from 80 to 95% marketable coal have been shown to correspond with reductions of from 60 to 30% of the original impurities present in the coal.

The influence of coal cleaning on the clinkering characteristics of coal has also been studied. The bituminous coals of Alberta have, as a rule, ash with high fusion temperature, although individual pieces of coal sometimes have easily fusible ash. The ash from washed coal, in most of the samples so far tested, has been more fusible than the ash from the raw coal, but the difference is sometimes small or even reversed. Two photographs of sets of heated coal ash cones are shown in figs. 2 and 3. In fig. 2 the cleanest coal with 4.7% ash (float on 1.36 sp. gr.) has the most fusible ash, but there is little difference to be observed in the ash fusibility of the run-of-mine with 13.4% ash, refuse with 48.3% ash, or other cleaned coal samples with 8 and 10% ash. In fig. 3 showing curves of a low ash coal with a low fusion point, erratic fusibilities may be noted. Whilst there was little difference between run-of-mine coal with 6.9% ash, and the two cleanest coals with 4.9 and 5.9% ash the float on 1.55 sp. gr. solution, with 6.0%

ash, was very noticeably more fusible and the refuse, with 33.0% ash, was notably less fusible than the run-of-mine.

The wide range of fusibilities of ash to be found in a study of individual lumps of coal from the same mine are clearly shown in fig. 4. The specific gravity and ash content of each sample is shown. This is a striking example although as large ranges of fusibility are often met. The different colors of the heated cones, the varying fusibilities, and the marked tendency of one sample to puff up when heated, can be clearly seen.

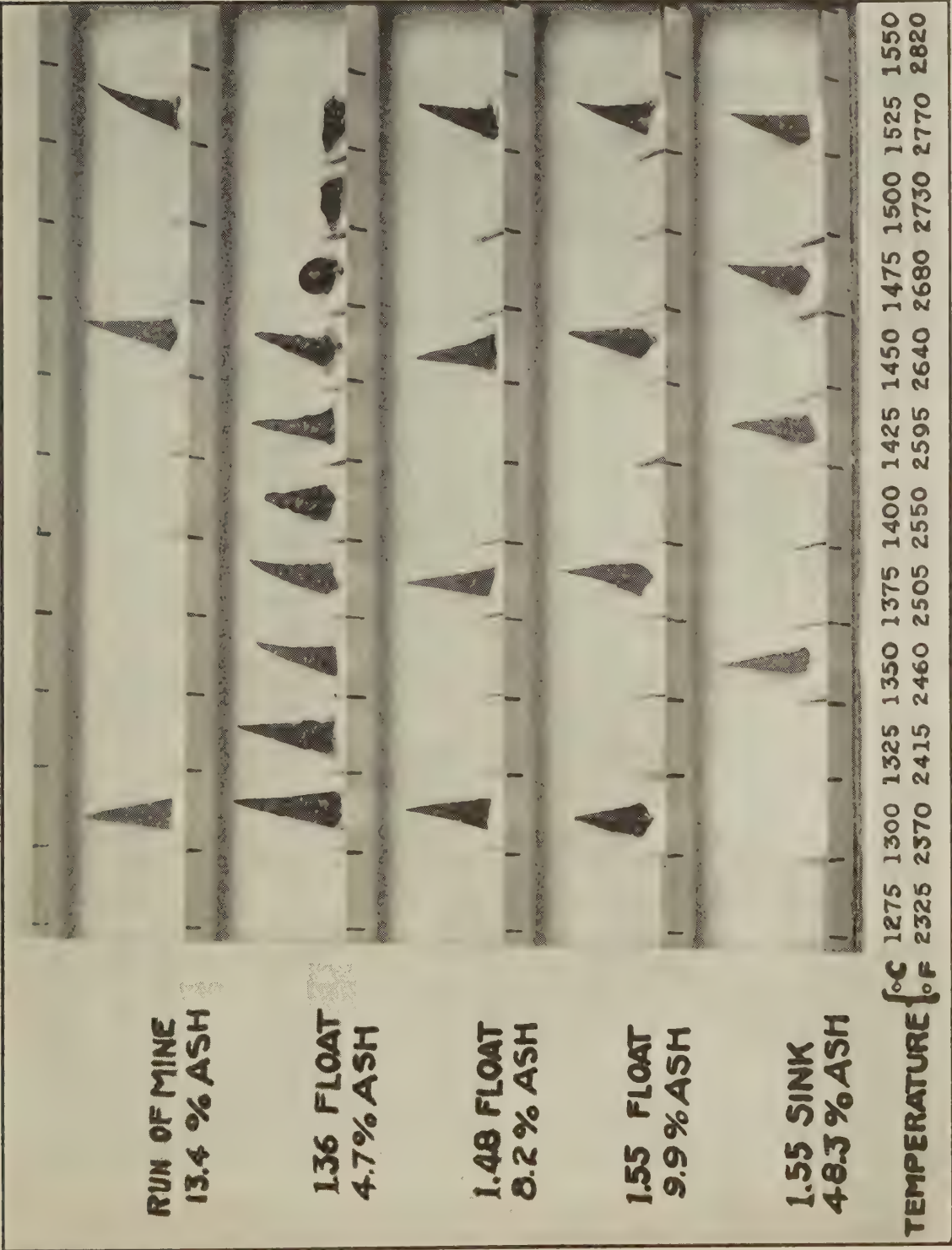


Figure 2.—Ash Cones from run of mine coal and from float and sink fractions.

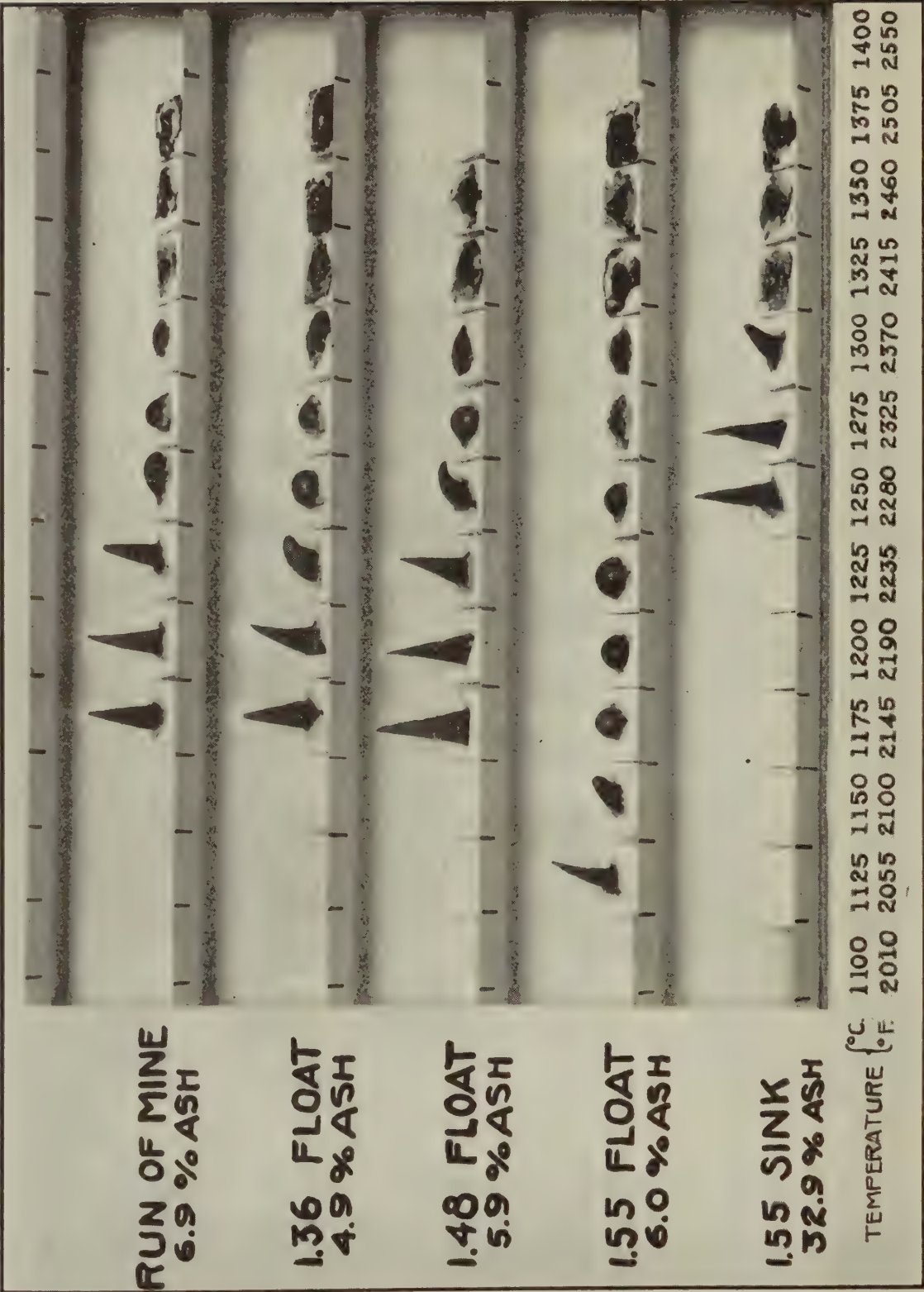


Figure 3.—Ash cones from run of mine coal and from float and sink fractions.

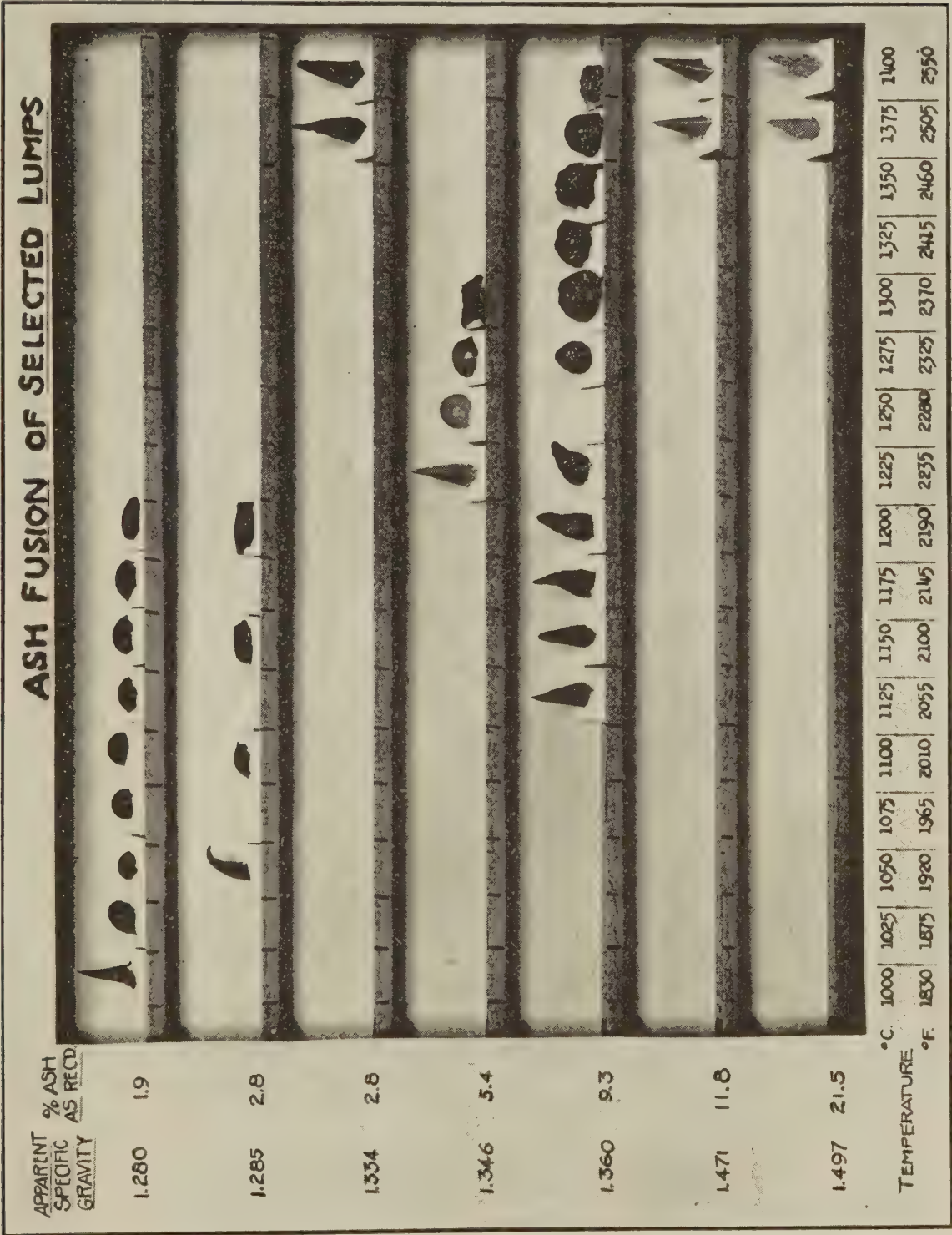


Figure 4.—Ash cones from selected lumps from one coal mine.

SPECIFIC GRAVITY OF COAL

Determinations of apparent specific gravity were made on 216 samples from 21 different mines. The results have been plotted graphically and separate charts are now available for many of the coal areas, showing the variation with ash of the specific gravity, cubic feet per short ton of coal in seam, and tons per acre foot of the coal.

In view of the rock, shale, clay or other impurities mixed with the coal it could not be expected that a simple relation would be found between the ash content and specific gravity of all samples even from a single mine. Nevertheless for many mines, and even for some coal areas, all points determined fall surprisingly closely on to a straight line in the chart.

One quite unexpected feature has been noticed. It had been supposed that the density fell with the rank of the coal, being highest with anthracite and lowest with lignitic coals. The low volatile coals from Anthracite and Canmore in the Cascade area tend to be slightly more dense than the other coals in the Province, but apart from this the density of the coal, determined with its moisture as it occurs in the seam, appears to be quite independent of the rank of the coal. In fact some domestic coals follow very closely to the Cascade area coals.

The total range of density of all samples examined is shown in the accompanying curve, fig. 5. Three density scales are given in this curve:—specific gravity, cubic feet per short ton in seam, and tons per acre foot in seam. It will be noted that, in spite of the wide range of coals included, the values fall within a comparatively narrow band for the low ash samples. The points are more scattered with the high ash samples, as is to be expected.

FURNACE TESTING

Tests were completed on the domestic gas furnace referred to in last year's report. A report of the tests has been submitted to the inventor.

BRIQUETTING

The briquetting investigation planned for the year had to be dropped. A sample of briquettes submitted by a local operator was tested and a report sent to the operator concerned.

SOLUBILITY OF COAL IN ORGANIC SOLVENTS

The chemical constitution of coal is receiving increasingly more attention, because of the possibility of the use of coal as a raw material for chemical industries. The extraction of montan wax from the German brown lignites has been a profitable industry for some time, and a German authority stated that such an industry could be economically developed on a coal yielding 8% montan wax. This wax is used extensively in the manufacture of boot polish, special waxes, lacquers, electric insulation, etc. It was known that no Alberta coal resembles the German coals from which

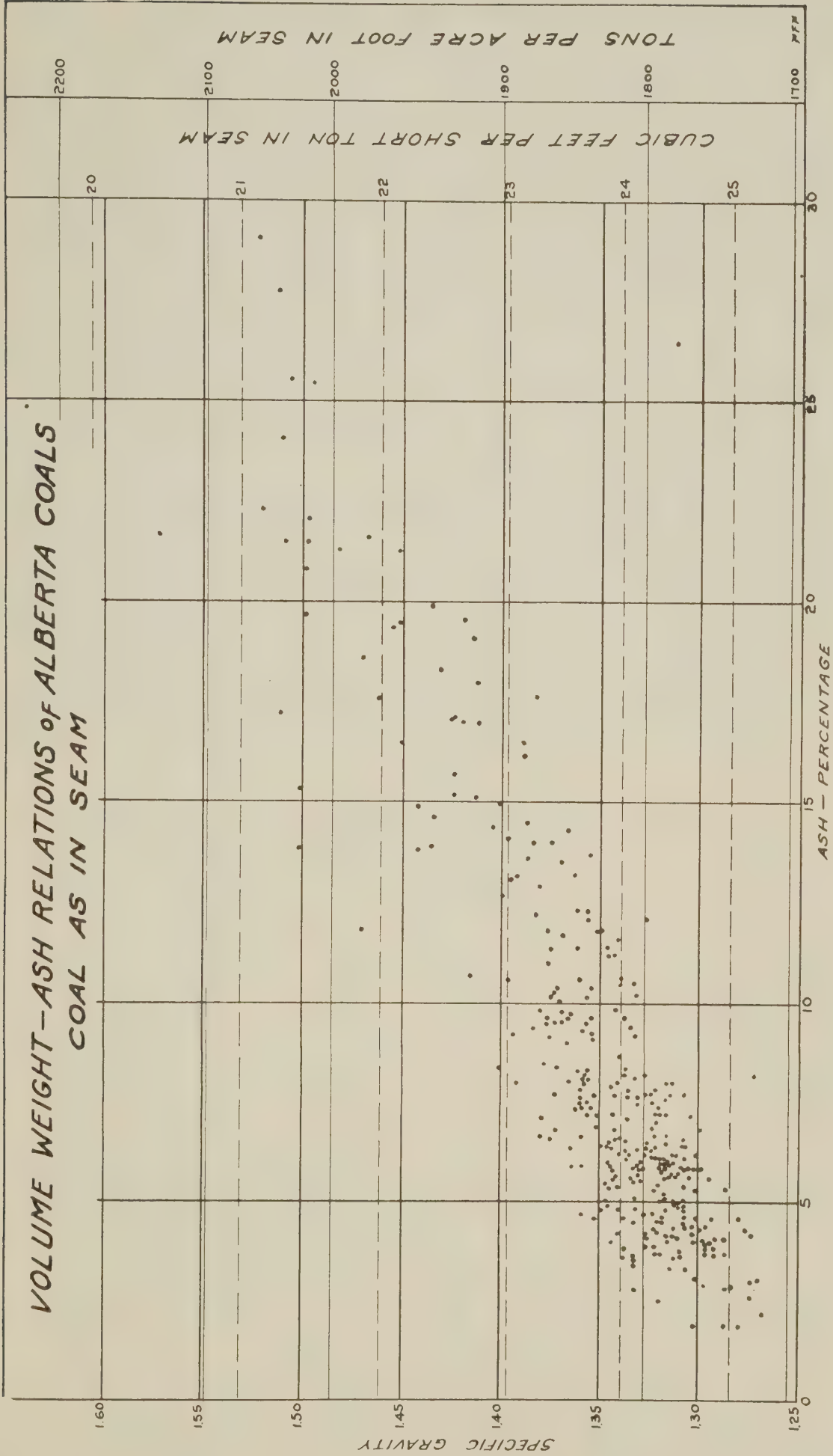


Figure 5.—Volume Weight—Ash Relations of Alberta Coals. Coal as in Seam.

montan wax is prepared, but it was thought possible that some coal might be found which would yield a similar substance. In view of this, methods were developed and apparatus devised for the study of the solubility of coal in organic solvents. Ten coals selected to cover several types have so far been tested. The amount of material extracted from any coal depends on the coal, the solvent and the temperature of extraction. The temperature of extraction can be raised by the use of high pressures, which is particularly desirable with solvents of low boiling point. The extract obtained from some Alberta lignites resembles the crude montan wax described in the literature. The yields, however, in the coals tested have been small. The material extracted has ranged as high as 40%, but the higher yields were from bituminous coals with a type of solvent other than that used for wax extraction, and the extracted material in this case did not resemble montan wax. This work was carried out by H. G. Reiber under the supervision of the staff of the Fuels Division.

The results obtained, which must be regarded as of a preliminary nature only, are shown in Table II. The solubility of coal in benzene is increased to a remarkable degree by the use of high pressures, but it is probable that materials other than montan wax are thus extracted. The published accounts of the montan wax industry indicate that benzene at ordinary pressures is the solvent used. No Alberta coal has yet given a notable extract under such conditions. Further work is in progress following modified methods and with additional coals and solvents.

TABLE II.
SOLUBILITIES OF TEN ALBERTA COALS IN ORGANIC SOLVENTS

Source of Coal	Analysis of Coal		Solubility in Benzene-alcohol mixture %	Solubility in Phenol %
	Volatile Matter %	Fixed Carbon %		
Luscar	28.7	71.3	0.3	29.8
Coleman	29.6	70.4	1.9	41.9
Mountain Park	34.8	65.2	12.5	36.9
Beaver Mines	35.5	64.5	9.6	28.8
Pincher Creek	35.8	64.2	2.5	43.1
Drumheller	41.9	58.1	5.0	23.6
Gleichen	43.0	57.0	4.1	14.3
Coalspur	43.5	56.5	5.7	21.5
Lethbridge	43.7	56.3	10.6	27.6
Clover Bar	44.9	55.1	2.4	19.0

Note that the benzene-alcohol extractions were made under pressure of about 250 pounds per square inch, that is, at 210°C, whilst the phenol extractions were made at 183°C, the boiling point of the solvent at ordinary pressures.

Analyses and results are expressed as percentages of dry, ash-free coal.

LIQUEFACTION OF COAL

Tests by J. Ivon Graham and D. G. Skinner

In 1929 six samples of Alberta coal were sent to Birmingham University, England, for hydrogenation tests. Hydrogenation of coal is the process commonly associated with the name of Dr.

Friedrich Bergius of Heidelberg, Germany. The tests in Birmingham were made through the courtesy of Mr. J. Ivon Graham, who is a recognized authority on this work. The report, which is summarized below, was prepared by J. Ivon Graham and D. G. Skinner.

Treatment: 200 grams of coal, suspended in 100 grams of phenol, treated with hydrogen for four hours at a temperature of 425-430°C. The hydrogen was charged into the bomb at a pressure of from 55-60 atmospheres when cold, and the resultant pressure when hot rose to as high as 182 atmospheres, or nearly 2700 lbs. per square inch. After treatment and cooling the gas was removed and a second charge of hydrogen, followed by 4 hours heating as before, was given the second day.

Coals tested: A from Cascade area; B and C from Mountain Park area; D from Coalspur area; E from Pembina area; and F from Tofield area.

The results show a 50% liquefaction with the coking bituminous coal (C) from Mountain Park area. The yields are less with both lower and higher rank coals. The yields shown were for two treatments only, continuous operation would be expected to give higher yields of oil. Higher yields could also be obtained by the use of a suitable catalyst.

Apparatus and equipment for the hydrogenation of coal is now available in the high pressures laboratories in the Chemistry Department of the University of Alberta, and work is in progress under the direction of Dr. E. H. Boomer.

TABLE III.
HYDROGENATION RESULTS

	A	B	C	D	E	F
Analyses of Coal as Tested:						
Ash	3.9	9.2	5.9	8.3	4.9	6.4
Moisture	1.8	1.3	0.8	9.8	21.7	27.1
Volatile matter	12.6	21.8	32.2	31.2	27.4	27.8
Fixed carbon	81.7	87.7	61.1	50.7	46.0	38.7
Details of Test:						
Maximum pressure 2nd day, atmospheres	160	160	164	171	179	182
Aggregate drop in pressure, both days, atmospheres ¹	11	16	22	18	10	19
Yield of Products²:						
Light oils, distilling below 150°C %	5.1	2.6	3.6	7.6	3.4	7.4
Heavy oils, soluble in phenol and chloroform	17.5	29.2	46.9	27.6	18.1	29.8
Total liquid yield	22.6	31.8	50.5	35.2	21.5	37.2
Brown powder, soluble in phenol but insoluble in chloroform (partially hydrogenated products)	9.0	12.3	16.9	4.0	3.8	9.4
Residue, insoluble in phenol and chloroform	63.0	46.7	17.8	46.0	61.7	33.1
Gas	3.1	4.7	10.5	13.7	?	13.8
Water	1.3	4.1	6.1	3.6	5.9	8.7
Total	99.0	99.6	101.8	102.5	.....	102.2

Note: ¹This last value is an indication of the hydrogen absorbed by the coal.

²The yields of products are expressed as percent of weight of dry, ash-free coal.

GEOLOGICAL SURVEY DIVISION

BY J. A. ALLAN

The major part of the field work in 1930 consisted in continuing the surveys of the previous year on water supply in the Peace River-Grande Prairie districts, and mineral prospecting in the northeast corner of the Province respectively.

Attention is drawn to the basic fact that before the mineral possibilities, whether metallic, non-metallic, coal, petroleum or natural gas, water supply or road materials, in any district can be determined it is necessary to study and map the geological formations and structural conditions in that area. It is by this method and this method alone that the geological survey division can be of service in expressing an intelligent opinion on the mineral possibilities, on the mineral resources, including water supply, petroleum, etc., in any district. Geological information on many parts of Alberta is yet meagre, and until much more geological data of a general character are obtained on certain parts of Alberta, no authentic opinion can be expressed on the occurrence, extent or economic value of mineral or water resources that may be within that area. For example, an interpretation of the water supply in the Peace River district necessitates a general knowledge of the geology of Alberta over a much larger area than that represented by the Peace River districts. Or again, details on coal seams in any district cannot be obtained without a knowledge of the general geology of the territory adjoining that district where the coal deposits occur.

I.—WATER SUPPLY SURVEY

In 1929, field investigations were commenced by R. L. Rutherford on the area from McLennan west to Spirit River and north of the Peace River valley to Waterhole and Fairview. The results of this work have been published as Report 21. In 1930 the field work was continued northward to Battle river and along the western interprovincial boundary near Pouce Coupe and Rolla. A progress report by R. L. Rutherford on the results of field investigations in 1930 is given later.

The maximum information on the general geology of this part of the Peace River area has been obtained from surface conditions. The possible water-bearing horizons have been described and the approximate depths to these horizons determined.

II.—MINERAL EXPLORATIONS IN THE PRECAMBRIAN NORTH OF LAKE ATHABASKA

The primary purpose of the explorations north of Lake Athabaska has been to delineate by geological examinations, particular regions or zones within the Precambrian area which might offer

possibilities for the presence of metallic mineral occurrences of economic importance and thus warrant more intensive investigations. The results of the two seasons' operations indicate that there appears to be no great probability of metallic mineralization anywhere within the area. On the other hand, the two seasons' work have given considerable scientific information on the geology of this portion of the Precambrian shield, information which will be of considerable value in throwing additional light on the problem of Precambrian geology.

About two thirds of the area north of Athabaska lake has been examined in some detail. The remaining third, which is rather more inaccessible than the others, has not yet been examined.

A report by A. E. Cameron and H. S. Hicks on the explorations to date is attached hereto.

III.—OTHER FIELD INVESTIGATIONS IN 1930

J. A. Allan examined a deposit of talc reported as occurring in Alberta west of Banff and south of Castle. It was found that the deposit, which was being tested by diamond drilling, occurs on the British Columbia side of the boundary. However, if this is opened up the talc will be transported to the railway through Alberta.

Some of the new wells in Turner Valley were visited and information on recent development in this oil field was obtained. The Wainwright field was also revisited.

Dr. P. S. Warren of the Department of Geology of the University spent about a week with R. L. Rutherford continuing the geological survey along the Athabaska valley west of the foothills.

Compilation of water well data was continued. Data on 422 wells in Central Alberta were obtained in September by J. Tatham. In addition, about 50 other wells have been recorded. Most of the data were obtained from the drillers in the various districts, as it has been found that farmers can supply very little useful information on their water wells. The districts examined extend from Millet south to Airdrie, northeast to Irricana, Beiseker, Acme, Trochu, Ardley; from Red Deer east to Buffalo lake, Stettler and Fenn; from Edmonton east to Vegreville, Wainwright, Vermilion, Kitscoty and Lloydminster; and on the north side of the Saskatchewan from Redwater to Smoky Lake, Vilna, Frog Lake and Lea Park. Water samples were collected from 19 wells and analyzed by Mr. J. A. Kelso, Provincial Analyst.

Samples of ochre were collected from a deposit east of Pakan. Further examination of this mineral will be made in the laboratory.

Dr. Wallace, Dean Wilson and Dr. Allan made a trip by airplane from Cooking Lake to Fitzgerald and visited the Cameron-Hicks party in the Precambrian area. A number of flights were made to the east boundary of Alberta and between lake Athabaska and the north boundary of the Province, and a general idea was obtained of the geology and physiography of about 10,000 square miles of the Precambrian shield. Observations en route to and from Fitzgerald added much new information on the geology and geography of Alberta.

With the approval of the Director, Geological Survey, Ottawa, the services of Dr. L. S. Russell were obtained for three weeks in October, to complete the work he carried out for the Council in the foothills of southern Alberta in 1929.

WATER SUPPLY AND OTHER GEOLOGICAL SURVEYS

By R. L. Rutherford

Water Supply.

During the field season of 1929, the writer covered an area within the Peace River country relative to the water supply. This area covered a portion of the settled districts where there is a shortage of water for domestic purposes. The results of this survey are set forth in Report No. 21 of the Research Council.

Other outlying districts within this general area are being settled, and during part of the field season of 1930 these were examined. The writer spent two months in these areas, covering districts somewhat removed from each other. In addition, some further observations were made on the area covered in Report No. 21.

One of the outlying districts examined, commonly referred to as the Battle River district, is situated about 50 miles north of Grimshaw, to which it is connected by an automobile highway. This is a newly settled district about 30 miles long and from 10 to 15 miles wide.

The succession of strata exposed along the Peace river north of Peace River to Vermilion was examined in a general way, taking the river trip on the Hudson's Bay Company boat. Later the various streams crossing the Battle River district were traversed. Although exposures of bedrock are few within the Battle River district, there were sufficient to determine the main geological features.

This area is underlain by the St. John shales, which is a marine formation averaging about 600 feet thick at Peace River. Part of this formation has been eroded from the Battle River district, but 350 to 400 feet of these beds underly the general level of the district.

The character of these is such that it seems unlikely that good water horizons occur in them. No deep wells have been put down, but during the summer of 1930 several shallow wells were bored. The water obtained in these is very hard and in many cases not fit for general domestic use. The writer is of the opinion that the water problem will become more acute in this area as agricultural development continues.

During 1930 the Northern Alberta Railways were constructing a railway extension for a distance of 15 miles northwest from Fairview. Coincident with the construction, many new settlers were taking up land for many miles beyond what will be the new end of steel when the extension is completed.

A traverse was made of this area northwest of Fairview, along the north side of the Peace as far west as range 8, township 87, or to a point about 50 miles northwest of Fairview. This district is

included in the area covered by the Soil Survey Report of F. A. Wyatt and O. R. Younge (Report No. 23).

As yet there is very little settlement beyond 20 miles from Fairview, but the best of the available land has all been taken up. It is the writer's opinion that the water conditions will be the same here as in the Fairview district, although there may be some local exceptions, due to the presence of glacial deposits.

A series of uplands occurring in range 87 and 88, known as the Clear hills, are drained in part to the south towards the Peace, some 15 to 20 miles distant. Part of the water from this drainage may follow underground channels relatively near the surface, and consequently ground water may be present in some quantity over part of the area. It is felt, however, that such conditions will not apply to the district between Fairview and the Montagneuse river, some 30 miles to the northwest.

Should drilling at Fairview prove that the Dunvegan formation contains good water horizons of considerable lateral extent, then it is possible that similar horizons would occur in the same formation beneath this area. Furthermore, drilling depths to this formation would be, on the average, much less than at Fairview. The top of the Dunvegan formation, which occurs at a depth of about 350 to 400 feet at Fairview, would probably be less than 200 feet west of range 6 in township 86.

Further observations were carried out on the Pouce Coupe river along the west side of Alberta, continuing a preliminary investigation made in 1929. There is considerable new settlement in Alberta along the west side of the Province, south of the Peace and adjacent to the Pouce Coupe and Rolla districts in British Columbia.

A general survey of water conditions at Pouce Coupe, Rolla and Dawson Creek, in British Columbia, was made, since water conditions prevailing in these districts that have been settled for some time should give a fairly accurate idea of what to expect in the Alberta districts to the east of the Provincial boundary. Summarily it may be said that these settled districts in British Columbia have not obtained a suitable supply of ground water, although several deep wells have been drilled. Consequently similar conditions are likely to obtain in those parts of Alberta lying to the east.

A brief examination was made of the Fort St. John district where the Dunvegan strata occur at the surface. No drilling tests have been made in this district; consequently the possibilities of this formation have not been determined in the only settled district where the Dunvegan strata occur at the surface.

A general examination was made of the area in the western part of the Province traversed by the new extension of the Northern Alberta Railway from Hythe to Dawson Creek. The strata exposed along the Red Willow river were examined from a point south of Halcourt west to near the boundary of the Province. These are coal-bearing south of Halcourt, and information relative to their stratigraphical horizon is important for purposes of general correlation.

A traverse was made from the Smoky river east to Sturgeon lake.

Volcanic Ash.

An investigation was made of a reported occurrence of volcanic ash in Marten mountain at the east end of Lesser Slave lake. The writer was taken to the area by Mr. H. Hall, Forestry Supervisor of Slake Lake. An optical examination of a sample of the rock in 1929 had proved it to be of volcanic ash, a common ingredient in cleaning and scouring materials. This deposit occurs near the top of the west end of Marten mountain. It would require considerable prospecting to determine its thickness, but it is in place and at least one foot thick.

Areal Geology between Athabaska and Saskatchewan Rivers.

Early in June an examination was made of the district along the Athabaska at Fort Assiniboine. During the latter part of the season this work was continued around Athabaska Landing. A general preliminary survey was made over the area lying north of the Saskatchewan from Clyde east to St. Paul and Cold lake and north to Lac la Biche, and information relative to ground water supply and distribution of coarser glacial deposits was obtained.

During this work an examination was made of the bituminous sand occurrence west of Barrhead on which several claims have been filed. The writer believes this material to be a mass brought here by glacial action and not a deposit in situ, although it is rather large for an occurrence of this nature.

THE PRECAMBRIAN AREA OF NORTHEASTERN ALBERTA

By A. E. Cameron and H. S. Hicks

Introduction and Acknowledgments.

The season's work covered most of the north half of the Fitzgerald sheet. Owing to the relative inaccessibility of the area arrangements were made with the Commercial Airways Company for the transportation of the field party into the area, contact and movement of the party at and between specified points within the area, and its final return to Edmonton. These arrangements were carried out by the Company in a very efficient way. The transportation of the field party and its equipment, including a 16 foot Chesnut canoe (see Fig. 6) into the area, the contact at specified points and given dates, and movement of the party by plane from one lake to another in a territory which is uninhabited and completely unfamiliar to the pilots, all contributed greatly to the successful completion of the season's work.

Three caches of food supplies were established by dog team during the winter of 1929-30 at specified points within the area by Mr. Frank Conibear of Fort Smith. The placing of these caches at the required points by Mr. Conibear proved of immense help in the season's operations.

The field party, consisting of H. S. Hicks and G. A. Harcourt, left Edmonton early in June. It proceeded north by rail and

steamer to Fitzgerald, where on June 7th it was met by Pilot I. Glyn-Roberts and was carried over 50 miles of difficult country to the south end of Charles lake in less than 30 minutes.

With the cache at the south end of Charles lake as a base, the field party worked south and east by canoe and portage. Throughout the greater portion of this region there are few traces of canoe travel, and consequently the travel between many of the little lakes of the region necessitated locating and cutting a portage overland. Nevertheless the party, during the month of July, worked its way to the east boundary of the Province at a point about latitude N. $59^{\circ}30'$, making a geological reconnaissance of over 250 square miles of country. The party returned to the base cache on Charles lake on July 2nd.

A. E. Cameron, travelling by plane, joined the field party at Charles lake early in July. During July the enlarged party geologically examined the area for a distance of about 10 miles on each side of Charles lake, with several traverses by portage and canoe both east and west. This somewhat detailed geological reconnaissance covered over 350 square miles of territory.

The original field party, early in August, made a canoe and portage traverse east from Charles lake to Andrew lake, studying the geology of the adjacent territory. Later they were transported by plane to Leland lakes. The balance of the season's field operations consisted of geological reconnaissance of the territory adjacent to this water system and southwest.

Messrs. Wallace, Allan and Wilson, members of Council, visited the field party early in August, being transported to and from the field by a Commercial Airways plane piloted by W. Sherlock. Two extensive flights were made over the Precambrian area at this time and an excellent general impression of the geological features of the region was obtained in this way. Returning south, the party circled over the gypsum area near Peace Point and made a general air reconnaissance of the country south of Peace river and west of lake Claire. This territory, as seen from the air, is a broad flat plain, presumably largely muskeg, well forested with spruce and poplar. Some excellent stands of spruce were observed in the country between Peace river and lake Claire. No features of geological significance were noticed within the area, and in particular no evidence was seen of a southern extension of the gypsum rocks.

As a result of all these operations, approximately 1300 square miles of the Precambrian area of northern Alberta were covered by geological reconnaissance during the summer. This area is fully four times as great as that examined the year before, showing clearly the advantage in the use of aerial transport.

The map, Fig. ~~10~~¹², shows, within the notched boundary, the areas covered by mineral exploration parties during the two field seasons of 1929 and 1930.

A full report on the geology of the region cannot be given until the several hundred rock specimens collected by the field party have received a detailed examination. The broader geological features are, however, fairly clear and are given later.

Summary and Conclusions.

An area of over 1200 square miles within the Precambrian area of northeastern Alberta, comprising practically the north half of the Fitzgerald map sheet, was geologically examined during the season. The examination showed that the majority of the area is underlain by granites or granitic gneisses. In two regions, the Charles lake and Leland lake areas, there is evidence of the intrusion of a granitic mass into a pre-existing rock mass. Changes in the earlier rock types due to the intrusion have gone so far that practically all evidence of their original nature has been destroyed. Although cracks and fissures in these rock types frequently contain quartz and pegmatite (see Fig. 7), no evidence of metallic mineralization accompanying these later phases of the igneous activity were found. It would appear that the present exposed surface represents conditions developed fairly deep down in the intruded rock and thus close to the upper zone of the intruding igneous mass. If metallic mineralization did accompany the intrusion, the minerals must have been deposited at higher levels in the intruded rock that have since been removed by erosion.

These two areas, Charles lake and Leland lake areas, are thought to be the most promising areas for metallic mineral deposits, but no evidence of such deposits was obtained in the rather detailed examination made. It therefore would seem unlikely that extensive mineralized areas exist within this portion of the Precambrian shield.

Geology.

The topographic map of the region, prepared by the Topographical Survey of Canada, from aerial photographs made by the Royal Canadian Air Force, indicates two broad trench-like depressions trending due north across the area. The more easterly of these, which contains the basins of Charles and Cornwall lakes, appears to be a northern extension of the north-south chain of lakes which formed the most significant topographic feature of the region examined in 1929. The second or westerly trench is occupied by the basin of the Leland lakes and the upper portion of Dog river. Extended south it would approximately include the upper reaches of Slave river. These two trench-like regions appeared significant from a geological point of view and hence were chosen as the main field of study in the area. This significance was confirmed in the field.

The more easterly or Charles lake region is clearly a northern extension of the north-south chain of lakes examined last year. Many of the rock types encountered are similar to those seen further south and probably will be definitely correlated with them when the rock samples have been examined. These rock types, essentially gneisses and allied rocks (see Fig. 8) are largely the result of granitic intrusions into some earlier rock mass and indicate wide-spread igneous activity in this region at some period of Precambrian time. Accompanying or closely subsequent to the intrusion, fracturing developed on a broad scale, in a general north-south direction (see Fig. 9).

The rock types found in the Leland lake area are closely analogous to those of the Charles lake region, although they also show relationships with the rock types found in 1929 adjacent to Slave river further south. Laboratory examination of the specimens collected in the Leland lake district will probably clear up many of the difficulties which developed in the attempted correlations of rock types found in the regions north of Athabaska lake and east of Slave river in 1929. In the Leland lakes district, as in the Charles lake area, the rock types encountered indicate a region of granitic intrusion with the development of characteristic rock types. Here also fracturing has occurred on a large scale, and in a general north-south direction. All of these gneisses and schists are clearly the result of granitic intrusion into earlier rock masses. Greatly changed fragments and blocks of the earlier rock types (see Fig. 10) found within the gneisses are strongly suggestive of an original sedimentary rock type, and it is quite probable that these two areas represent remnants of ancient, presumably Tazin, sediments which were engulfed and partially digested by igneous granitic intrusions. The relatively soft and less resistant character of these rock types, together with the prominent fracturing, account for the pronounced north-south trend of all the lakes, large and small, that lie within these regions, and which is so clearly shown in the topographic map.

The remainder of the region examined appears to consist largely of granites and granitic gneisses. From Slave river east to Leland lakes the country is underlain by a massive grey granite containing opalescent quartz, and granite gneiss and similar rocks form the greater part of the bed rock in the area between Leland lakes and Charles lake (see Fig. 11). The outstanding characteristics are a coarse texture and an abundant development of opalescent quartz. Gneissic areas are common, but are localized to small areas or patches usually adjacent to the small lakes of the regions. East from Charles lake a dense red gneiss, which also forms a prominent geological feature of the Charles lake area, predominated, but coarse granitic phases are common and these increase in quantity towards the east. In the vicinity of Andrew lake occurs a grey granite and associated grey gneiss without opalescent quartz. On further study this grey granite will probably correlate with the grey granite which was found in 1929 in the area northeast of Big Point on lake Athabaska.

The simplest and probably most nearly correct interpretation of the general geology of the whole area is that granitic magmas of wide extent intruded some earlier overlying rock, probably sedimentary in origin but quite siliceous in character. This granitic magma, now represented by the more purely granite types of rock within the area, intruded absorbed and digested more or less thoroughly, great quantities of the overlying material. All the various rock types encountered may well have been developed by this intrusion and the effects of the added material on the liquid solutions from which they formed. Undoubtedly the present surface represents conditions well down in the contact zone, much overlying material having been eroded. The Leland lakes and Charles lake

areas may well represent fragments of large blocks of the overlying material which foundered into the intruding magma but were incompletely absorbed by it.

The principal objection to this explanation lies in the great areal extent that has to be assumed for the intrusion. It is possible, however, that the region represents not one but several intrusions, more or less contemporaneous.

Metallic Mineral Possibilities.

The most favorable conditions for metallic mineral development are where masses of igneous rocks have intruded pre-existing rock masses, especially sediments such as limestone or altered extrusive igneous rocks such as lavas or other volcanic materials. As the metallic mineral-bearing solutions largely accompany the last phase of igneous activity, they are to be looked for associated with quartz and pegmatite emanations filling cracks and fissures developed by the stresses resulting from such intrusions in the pre-existing rocks or in the already solidified or partially solidified intruding rocks.

Within the regions examined, the two areas, one about Charles lake and the other about the Leland lakes, show extensive intrusion of granitic rocks into pre-existing rock masses. The rock associations present, however, appear to indicate that the absorption or digestion of the intruded rock by the intruding rock has been very great, in some cases almost complete, so that there are no remnants of the older rock masses remaining. Presumably the less altered portions of these older rock types have been eroded away during the long interval of time since the intrusion, as only remnants of the greatly altered, partly absorbed, lower portion of the older rock remain, or the older rock shows itself only in the modifications its absorption has made to the character of the intruding rock. Whatever later emanations may have come from the intruding igneous mass to fill cracks and fissures in the older rock have also been eroded, and with them have gone any metallic mineralization that may have developed. Thin stringers and veinlets of quartz and pegmatites are to be found abundantly in many of the gneisses of these regions, and occasionally extensive pink pegmatite and quartz veins cut granites and gneisses alike (see Fig. 7). They are, for the most part, short and discontinuous, and appear to represent late phases of the granite intrusion. Nowhere was there found any trace of metallic minerals, nor even any of the numerous non-metallic minerals which are always associated with metallic mineral occurrences.

Apparently if metallic mineral deposition did accompany or directly follow the igneous activity it must have occurred high above the present surface and erosion has worn it away. There may be local areas within the region where some mineralization still exists, but from the general appearance of the region they could not be extensive and if any such are found they can be expected to show as only small pockets without any great lateral and vertical extent.



Figure 6.—Commercial Airways plane CF-AKI at Andrew Lake—showing canoe tied to pontoon for transportation.

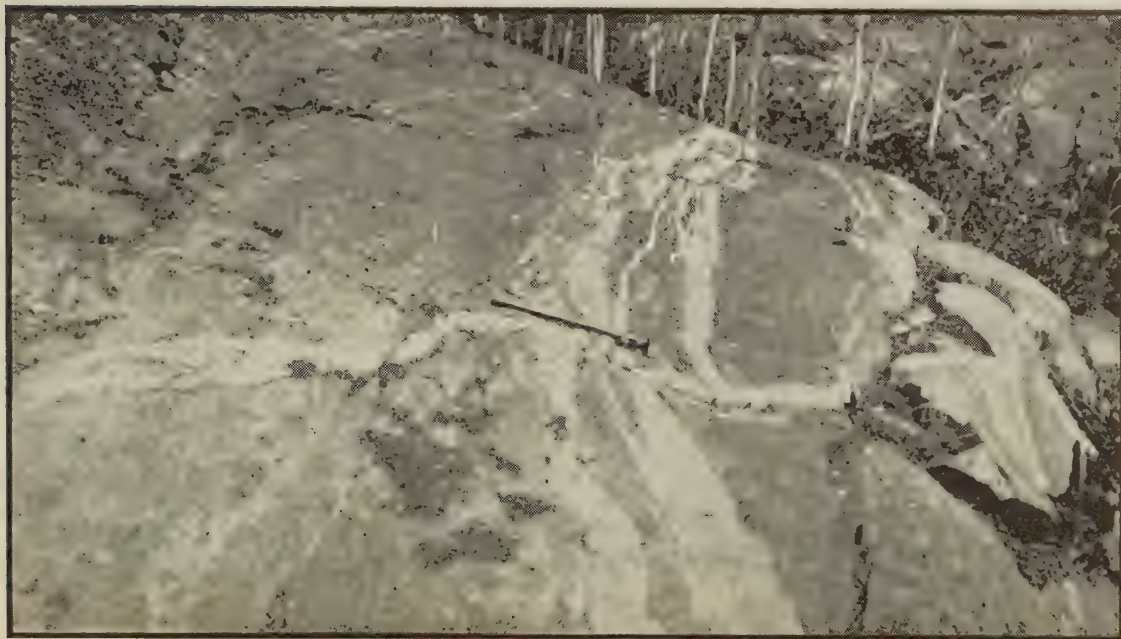


Figure 7.—Pegmatite and Quartz veins in Gneiss, Charles Lake area.



Figure 8.—Typical banded Gneiss. Charles Lake area.



Figure 9.—Aerial photograph of portion of Charles Lake area showing north-south trend of lake basins resulting from the post intrusion fracturing.



Figure 10.—Granite Gneiss with inclusion north end of Ashton lake.



Figure 11.—Granite cliffs on small lake between Leland lake and Charles lake.

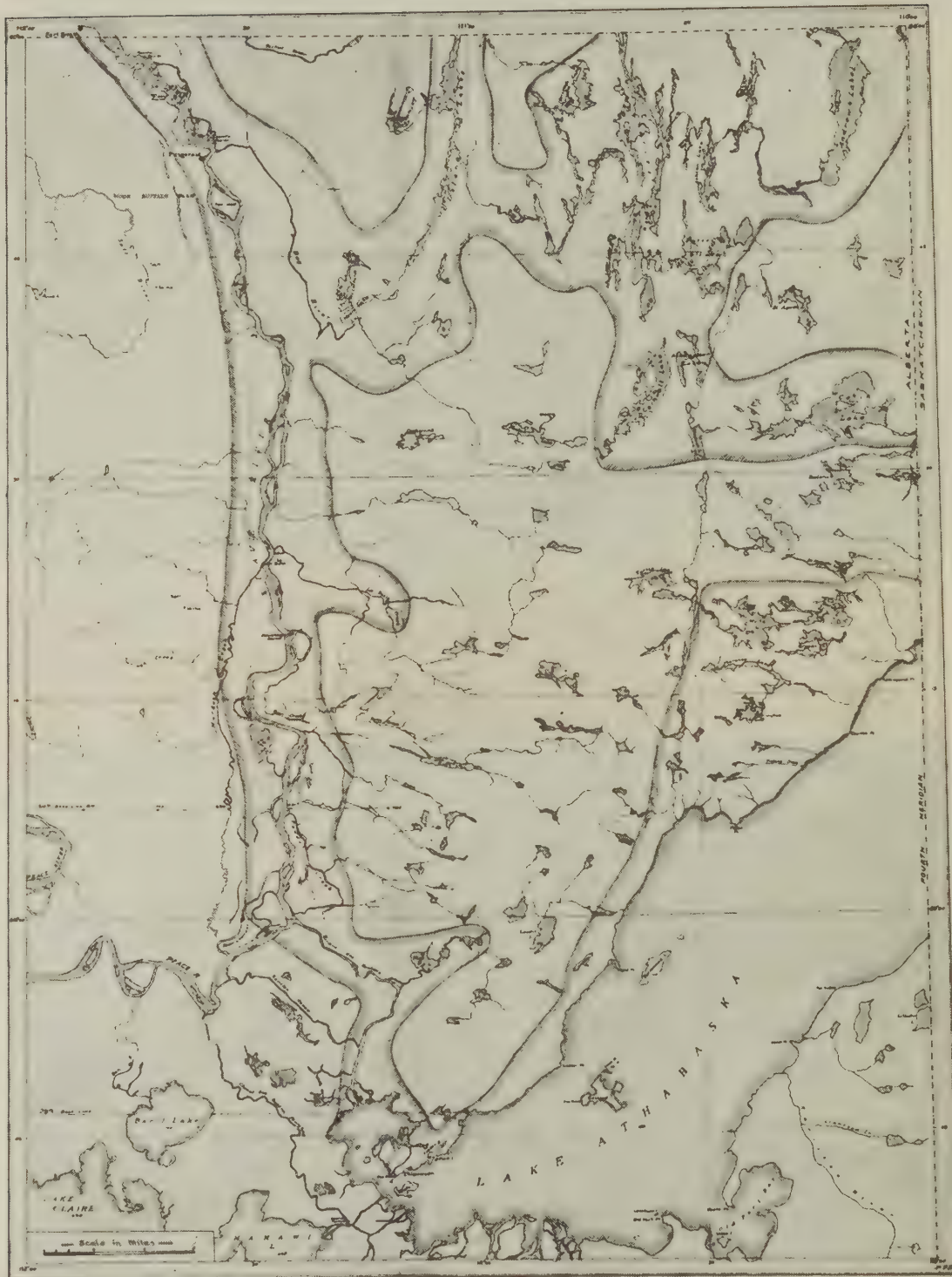


Figure 12.—Map.

PRECAMBRIAN AREA NORTHERN ALBERTA
(See page 33)

ROAD MATERIALS DIVISION

K. A. CLARK AND D. S. PASTERNAK

A two year program of bituminous sand development was commenced jointly by the Federal Department of Mines and the Research Council of Alberta, in 1929. The Department of Mines undertook to open a quarry on the Federal Government reserve on the Clearwater river and study the general problem of mining. The Research Council undertook to erect a separation plant beside the quarry and study the separation problem. The program was brought to a close during 1930.

The Tenth Annual Report gave an account of progress with the separation work during 1929. The Research Council overhauled its existing plant at Edmonton, bringing its design up to date. The plant was then dismantled, shipped north and re-erected beside the quarry on the Clearwater river. It was given a trial run before winter stopped further work. In the meanwhile an intensive laboratory study was being carried on to devise new operations to supplement former separation procedure and produce clean, dry, separated bitumen. The crude bitumen from the trial runs of the separation plant was shipped to the laboratory at Edmonton for work during the winter on the new cleaning and drying operations.

The laboratory work was completed during the winter and a procedure for eliminating water and mineral matter from the crude bitumen was decided upon. Equipment for installation at the separation plant was designed. The equipment was shipped north in the spring and was built into the plant. The plant was ready for operation by the first of June. It was operated during June, July and August. Data and observations regarding practical separation were secured. Fifteen thousand gallons of finished separated bitumen were produced and shipped to Edmonton. Part was used by the Department of Mines in trials of its specially designed asphalt mixing plant; part was used by the Provincial Department of Public Works for rural road surfacing experiments; and part is in storage.

Laboratory Work.

Results of work described in the Tenth Annual Report had shown that a general procedure suitable for eliminating water and mineral matter from the crude bitumen was that of settling, combined with evaporation of the last five to ten percent of water. The attempt had been made to break the water-in-oil emulsion and settle the water and mineral matter by maintaining the bitumen under pressure at a temperature considerably above the normal boiling point of water, but no settling of water occurred. By mixing dry salt with the bitumen to convert its water content into a heavy brine and then heating and settling it under pressure, good

separation of water as well as mineral matter was secured. The disadvantage of working under pressure led to examination of heating and settling at atmospheric pressure. Results were encouraging. Use of a salt brine as a separating medium to produce crude bitumen with its water content in the form of brine for subsequent settling was foreseen. Consequently separation tests were made using brine for plant water to determine whether salt water would affect separation adversely. It was found that it did not. It was pointed out that salt is a natural resource of the area in which the bituminous sands occur so that consequently the use of salt brine should not be a serious cost item in ultimate commercial practice.

Investigation of the elimination of water and mineral matter from crude bitumen was continued during the winter of 1929-30. The aim was to arrive, if possible, at a practical solution of the problem which could be used at the separation plant in the north during the 1930 season. The supply of crude bitumen from the trial run of the separation plant in the fall of 1929 was used in this work.

It was found that if bitumen containing about 27% water and 8.5% mineral matter was mixed in a steam-jacketed Werner and Pfleiderer kneading and mixing machine with salt (one and a half times the calculated amount for converting the water into a 20% brine), heated with mixing for thirty minutes at a temperature a few degrees above 100°C, to cause gentle frothing; and then allowed to settle over night in a vessel surrounded by brine at a temperature of 100°C, a settled bitumen containing from 4% to 6% of water and from 1.5% to 3% of mineral matter was obtained. About half the mineral matter was salt.

Since the separation plant in the north was continuous in its operation, it was considered desirable, if possible, to arrange for continuous elimination of water and mineral matter from the crude bitumen. It was thought that first settling could be accomplished by feeding hot, crude bitumen, containing water in the form of brine, to the bottom portion of a settling tank, the dimensions of the tank being such that the uprising current of bitumen would not be rapid enough to prevent settling of brine and coarser mineral particles. Laboratory equipment to test this idea was secured.

The laboratory equipment was similar to that subsequently built into the separation plant and indicated in Fig. 15. It consisted of a steam-jacketed mixing machine corresponding to that numbered 18 in the figure, discharging through a pipe to the bottom part of a cone-bottomed, steam-jacketed settling tank like that numbered 20. The laboratory tank was six and a half feet high above the top of the cone bottom, but was only one foot inside diameter. It had three sampling taps spaced four inches, two feet and four feet above the top of the cone bottom and an outlet at the six foot level which was the overflow for the tank. The laboratory set up also had a steam-jacketed reservoir tank for the supply of bitumen to be fed into the mixing machine for admixture with salt.

The results of a continuous run with the laboratory equipment are given in Table IV. The rate of feed of bitumen was about that necessary to displace the contents of the settling tank once each four

hours. The rate of feed increased considerably during the last two and a half hours. At first a steam pressure of eighteen pounds gauge was maintained in the heating jacket of the mixer. This pressure caused lively frothing of the bitumen and much evaporation of water. On reducing the steam pressure to about eight pounds, the bitumen still frothed at the discharge end of the mixer, but evaporation was greatly reduced. At six and a half pounds pressure there was very little frothing. Brine and settlings were withdrawn through the valve at the bottom of the settling tank each time samples of overflow bitumen were collected. Steam at atmospheric pressure was circulated through the jacket of the tank.

The results were not as good as expected. The decrease of settling action toward the end of the run was disappointing. However, there was hope that crude bitumen separated in salt brine would behave better than bitumen mixed with an excess of dry salt

TABLE IV.

Results of continuous settling run. Crude bitumen containing an average of 27% water and 8.5% mineral matter was passed continuously into a heating and mixing machine where one and a half times the salt required to convert the water content into a 20% brine was added to it. The bitumen passed from the mixer continuously to the bottom portion of a settling tank approximately six feet high, and after filling it, overflowed from it continuously. Analyses of the bitumen overflow are given. Analyses of the bitumen in the tank after settling for twelve and thirty-eight hours after completion of the continuous run are also given.

Time Running (hours)	Crude Bitumen fed (pounds)	Steam Pressure on mixer (pounds)	ANALYSES OF BITUMEN								
			Overflow			2' below overflow			4' below overflow		
			% Water	% Mineral Matter and Salt	% Mineral Matter	% Water	% Mineral Matter and Salt	% Mineral Matter	% Water	% Mineral Matter and Salt	% Mineral Matter
3.9	540	18									
4.2	570	18	1.8	1.9	1.1						
5.2	660	18	2.4	2.0	1.2						
6.4	825	8	2.9	2.5	1.4						
7.7	960	8.5	3.7	3.1	1.7						
8.7	1080	6.5	7.9	4.5	1.8						
9.9	1230	6.5	10.8	5.5	1.8						
10.9	1380	6.5	14.2	6.7	2.4						
12.0	1560	6.5	15.2	7.2	2.7						
12.4	1590	6.5	18.4	5.8	2.1	17.5	7.9	3.4			
(End of continuous run)											
24			6.9	2.2	0.5	10.1	4.5	1.3	10.9	6.3	2.5
50			6.6	2.4	0.5	6.4	2.1	0.5	9.5	3.3	0.8

and that a settling tank of larger diameter would be more effective than the small one. The bitumen in the tank at the end of the run settled fairly well upon being left for twelve hours, the water and mineral matter content decreasing to values comparable to those obtained by small batch settling tests. Since the plant in the north was to be run during the day only, some advantage could be taken of over-night batch settling. In any case, two continuous runs involving three-quarters of a ton of material each and many small batch tests had used up the stock of crude bitumen and there was neither time nor material for pursuing the matter further.

Attention was next turned to the continuous evaporation of the water remaining in the bitumen after the continuous settling operation. For this purpose a galvanized iron trough three feet long and four and a half inches wide was constructed, with rounded

bottom setting concentrically in a somewhat larger trough. Wet bitumen was fed into one end of the inner trough and dried bitumen was discharged through an opening at the other end. Oil maintained at about 165°C in the outer trough supplied heat for the evaporation. The bitumen was stirred by hand with a long paddle.

It was thought that as bitumen was displaced along the trough by the feed, evaporation would proceed and a discharge of dry bitumen could be secured. What actually happened was that the wet bitumen, on entering the hot, drier material already in the evaporator, frothed violently and the froth spread over the entire surface. Nevertheless, there was a rising gradient of temperature along the evaporator and a discharge of fairly dry bitumen was secured.

To overcome the spreading of the froth, the evaporator was divided into three compartments connected by openings at the bottoms of the partitions. This arrangement worked well. It was found that the feed to the evaporator could be regulated by watching the temperature of the bitumen in the second and third compartments.

A number of runs were made with the small evaporator and considerable information gained. It was found advantageous to connect the compartments by openings through the partitions at the height of the surface of the heating bath in addition to those at the bottom. This prevented large differences in levels of bitumen frothing at different temperatures in the three compartments.

Continuous settling of the dehydrated bitumen was tried. A high head was required to feed the light froth leaving the evaporator into the lower part of a settling tank. Also there was always a thick layer of froth on the surface of the settling tank which meant that the body of settling bitumen was being subjected to the stirring action of rising bubbles. It was decided that the final settling of dehydrated bitumen would have to be a batch operation.

A mechanically operated, steam-jacketed evaporator was secured and set up to discharge into the steam-jacketed settling tank previously described. The evaporator was similar in construction to the mixer numbered 18 in Figure 15. It was five feet long and was divided into three compartments. It had 10 square feet of heating surface. It had two sets of stirring paddles revolving in opposite directions. The heating surface of the evaporator was rounded so as to conform to the path of the revolving paddle blades. This prevented material from adhering to the heating surface and assured a good transfer of heat to the bitumen in the evaporator.

A number of dehydrating and settling runs were made with the evaporator and settling tank. Bitumen containing approximately 10% of water and 6% of mineral matter including salt was fed to the evaporator in a continuous stream from a steam-jacketed storage tank. It was found that with steam at 70 pounds gauge pressure in the jacket evaporator, the bitumen could be fed at the rate of 115 pounds per hour and a steady temperature of 115°C and 125°C maintained at the discharge ends of the second and third

compartments respectively. The dehydrated bitumen was run into the settling tank and held there for batch settling at a temperature of approximately 120°C. This temperature was maintained by steam at 20 pounds gauge pressure in the jacket of the tank. The results of a settling experiment are shown in Table V.

The evaporator did not remove all the water. Although the bitumen on leaving the evaporator was at a temperature of 125°C, it still retained about one-tenth of one percent water. Settling of the dried bitumen at 120°C gave excellent results, the mineral content being reduced to one percent or less. About half of this mineral matter was salt. It should be mentioned, however, that the mineral matter determinations reported in the table were made by dissolving the bitumen in benzene, filtering the solution through a Dulin Rotarex centrifugal extractor, and weighing the mineral matter retained. Subsequent determinations by ignition showed about two percent of mineral matter where the extraction method showed one percent. In other words, there was mineral matter in the bitumen fine enough to pass through the filter cardboard of the extractor.

Part of the explanation of the better settling of the dehydrated

TABLE V.

Results of batch settling of dehydrated bitumen. Bitumen containing approximately 10% water and 6% mineral matter and salt was fed continuously at the rate of 115 pounds per hour to a three compartment mechanically stirred evaporator with 10 square feet of heating surface, heated by steam at 70 pounds gauge pressure. The dehydrated bitumen passed into the settling tank at a temperature of 125°C and was maintained at a temperature of 120°C during settling by steam at 20 pounds gauge pressure in the jacket of the tank.

Time of settling (hours)	ANALYSES OF BITUMEN											
	Surface			2' level			4' level			5'8" level		
	% Water	% Mineral Matter and Salt	% Mineral Matter	% Water	% Mineral Matter and Salt	% Mineral Matter	% Water	% Mineral Matter and Salt	% Mineral Matter	% Water	% Mineral Matter and Salt	% Mineral Matter
3*	0.1	1.8	0.9	0.1	2.9	1.0	0.1	2.9	1.0			
20	0.1	0.8	0.4	0.1	0.9	0.4	0.1	1.1	0.4	0.1	1.4	0.5
44	0.1	0.6	0.3	0.1	0.7	0.4	0.1	0.7	0.4	0.1	0.6	0.2

*Duration of continuous evaporation during which settling tank was filled.

bitumen as compared with settling of bitumen containing five to ten percent of water is given by the temperature-viscosity relationship of the bitumen as shown in Figure 13. It is seen that the viscosity of the bitumen at 120°C is about one-fifth of its viscosity at 90°C which was about the temperature at which salt brine was settled. In addition to effects due to viscosity there is the effect of finely divided water retaining mineral matter. It has been observed throughout the bituminous sand studies that mineral matter and water contents of separated bitumens are related.

PLANT CONSTRUCTION

Laboratory work on the elimination of impurities from crude bitumen was brought to a close in February and drawings of equipment for the northern plant were made. The parts were constructed and shipped to Waterways on April 1st. There was barely time

to transport them across the river on the ice to the plant before the spring break-up. The work of installing the new equipment and of attending to the many details involved in putting the plant into running shape was commenced at once.

Quarry, plant and camp are illustrated by Figure 14.

The arrangement of parts of the separation plant is shown in Figure 15. The bituminous sand was moved into the plant from the storage platform by a chain conveyor, 1. This chain was the sort used in saw-mills for conveying sawdust and other waste. Three chains were placed side by side making a conveyor two and a half feet wide. The conveyor passed under a stout barricade, 2. Bituminous sand lumps on the chain were stopped by the barricade and were gradually sheared away by the links. The bituminous sand passed over the end of the conveyor and fell through a chute into a hopper, 3. This hopper accumulated a definite weight of sand and then dumped it, automatically, into the heating and mixing machine, 4, along with the quantity of treating reagent solution required.

The automatic hopper into which the bituminous sand fell was a double box mounted rigidly on a shaft. The two parts of the box were so shaped, in relation to the shaft, that when loaded there was an unbalanced weight over the shaft tending to cause rotation.

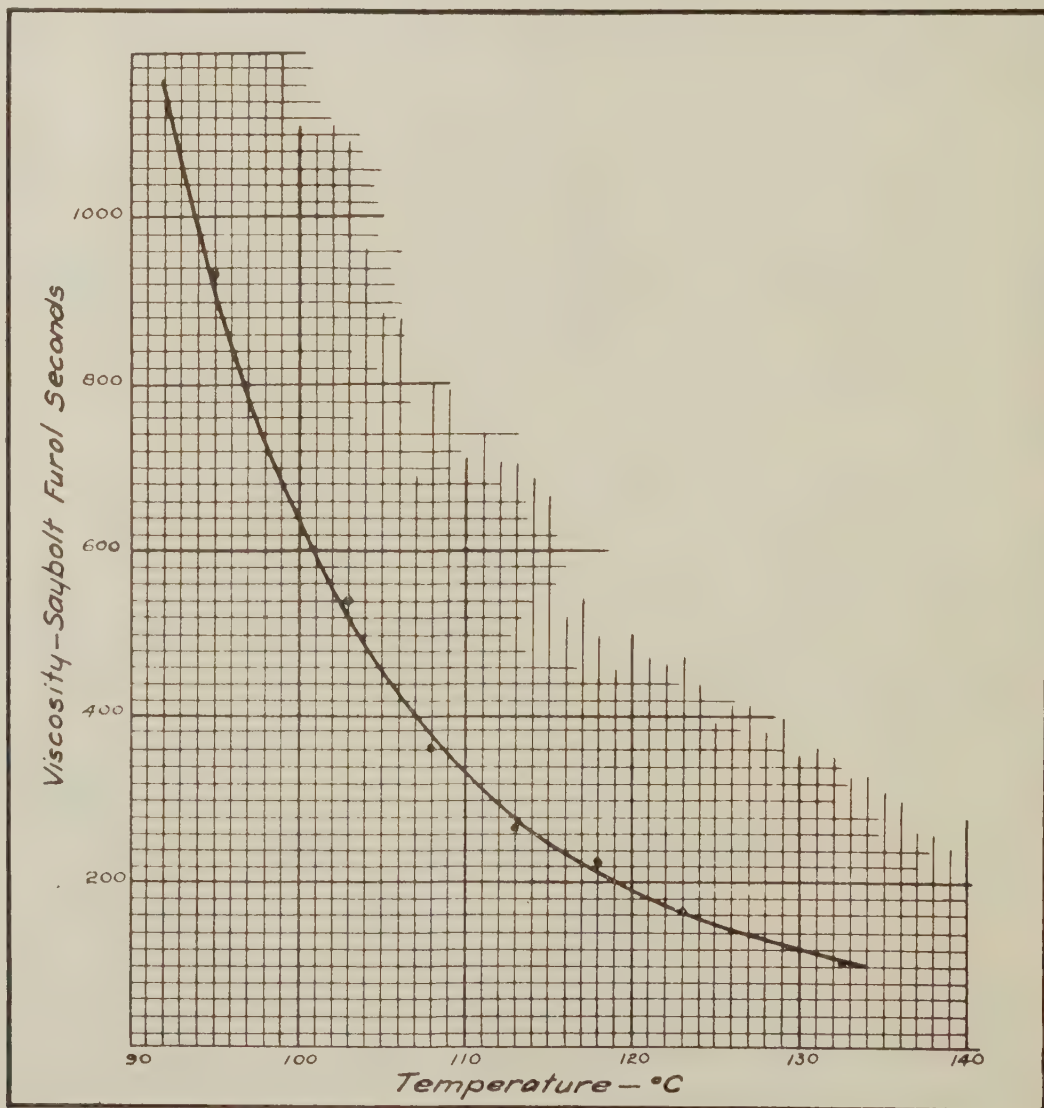


Figure 13.—Curve showing the relationship between viscosity and temperature for the bitumen used for the settling experiments.

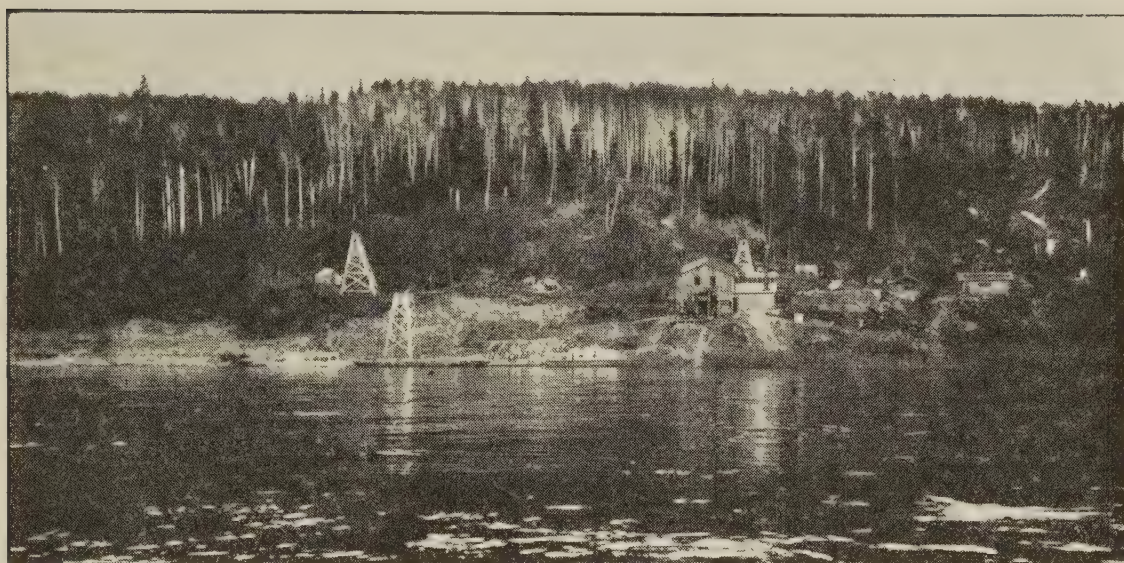


Figure 14.—View of the bituminous sand quarry and separation plant.

This rotation took place when sufficient load had accumulated in the box to lift a counter-weight and thereby release a catch. The box made half a turn, thus bringing its opposite side into position to receive sand from the conveyor. A tally attached to the shaft recorded the revolutions. The quantity of sand passed by the device during a period of time could be calculated from the number of revolutions and the weight which caused the hopper to dump.

Two other boxes were mounted on the same shaft that carried the box for the sand. The purpose of these boxes was to accumulate the right quantities of reagent solutions for a dump of bituminous sand and to discharge these solutions through pipes leading to the proper place for introducing them into the plant. Solution was pumped to these boxes in steady streams. The boxes filled till the level of the openings of the overflow pipes were reached. The solutions then overflowed through these pipes into funnels and attached pipes back to the solution reservoirs from which the solutions were being pumped to the measuring device. The quantity of solution which would be accumulated by the boxes could be adjusted by altering the lengths of the nipples of the overflow pipes.

Referring again to Figure 15, the bituminous sand was dumped by hopper 3, along with the right quantity of silicate of soda solution, into the heating and mixing machine, 4. This machine had a steam jacket for carrying steam at 100 pounds gauge pressure. Mixing was accomplished by blades mounted on a shaft. The pitch of the blades moved the contents of the mixer forward and fed it into a screw conveyor which discharged it. The mixer was, in fact, a clay and brick mill to which a steam jacket had been attached. The mixture of bituminous sand and silicate of soda solution, heated to 85°C , was discharged by mixer 4 into the trough 5 leading to the rotating screen 7. A second trough, 6, carrying a stream of hot water joined trough 5. The hot water stream dispersed the feed of treated bituminous sand into sand and finely divided bitumen and swept it through the rotating screen, 7, into the separation box, 8.

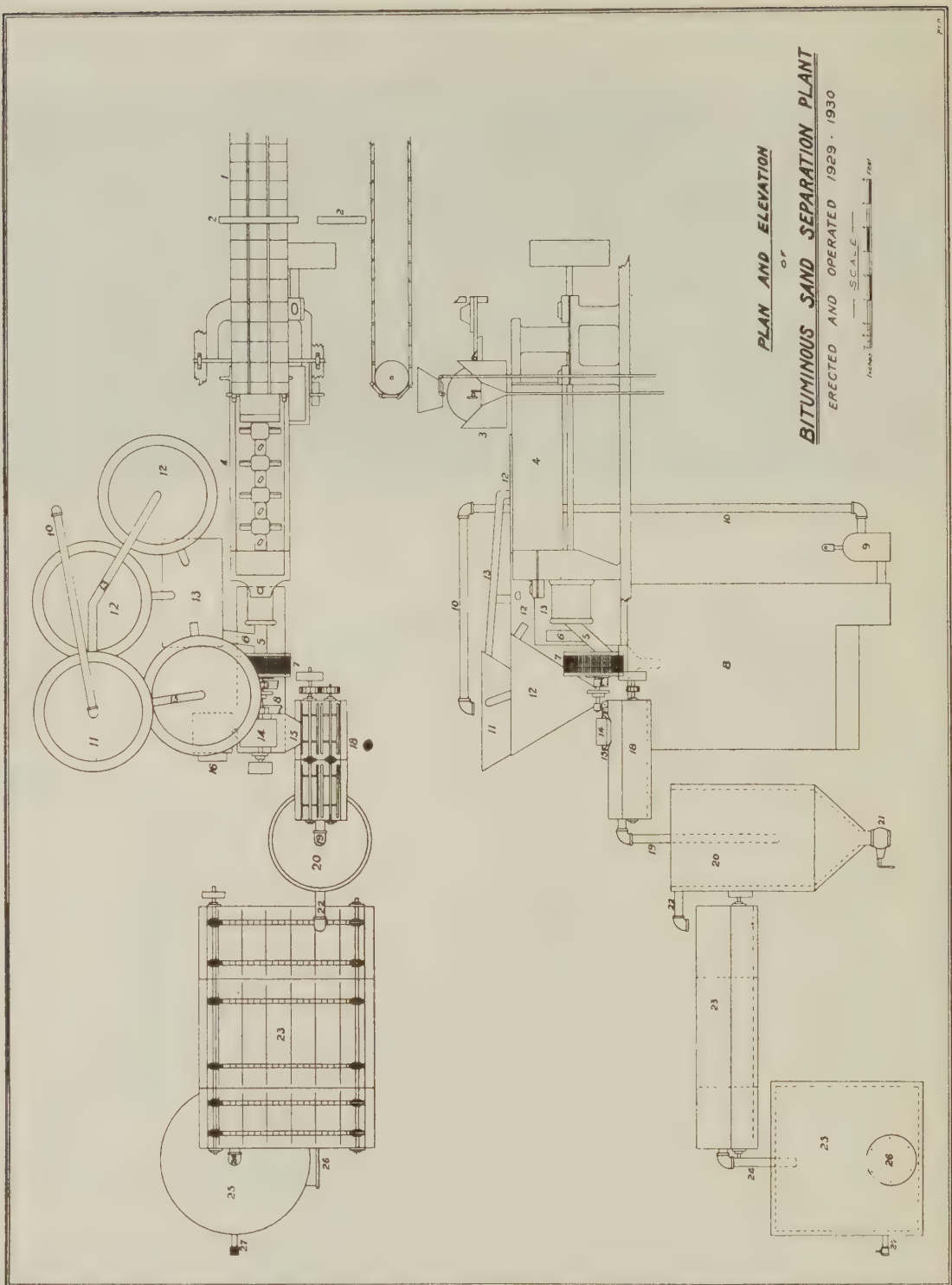


Figure 15.—Bituminous Sand Separation Plant.

The bituminous sand entered the separation box through the rotating screen and the funnel below the screen, at a point a few inches below the level of the hot water which filled it to an automatically controlled level. The bitumen floated to the surface and collected there as a froth. A rotating iron drum, 14, dipping into the layer of froth almost to the water level, picked up the floating bitumen and discharged it down a scraper and trough into mixer 18. The sand sank to the bottom of the separation box and was withdrawn along with water by the sand pump, 9.

The separation box was about seven feet long, two feet wide and eleven feet high. These dimensions were not deliberately

designed. The box was really two boxes from a former plant set one on top of the other and joined together. Originally, the boxes had screw conveyors working in V bottoms delivering into boots fitted with bucket elevators. The separation box was fitted with steam coils for heating its content of water. The water level was controlled by the overflow device, 16.

The sand particles of the bituminous sand were large and heavy enough to settle. But the silt and clay content remained suspended in the plant water. The presence of silicate of soda used in treating the bituminous sand helped to keep the clay suspended as it acted as a peptising reagent. As a first step in clearing the plant water of suspended clay, calcium chloride was introduced. The calcium chloride solution was metered by the second solution box of the automatic device, 3, and was discharged with each dump of bituminous sand through a pipe leading to the separation box. The calcium chloride coagulated the silicate of soda and clay.

Sand tailings and plant water were pumped from the bottom of the separation box by the sand pump, 9, through pipe 10 and were discharged into a Callow settling cone, 11. The sand settled in this cone but the current through it was too strong to allow the coagulated clay to settle. Consequently the overflow from cone 11 was distributed to the three cones, 12. The clarified overflow from these three cones flowed into a box, 13, where loss of temperature was restored by steam coils and then on through trough 6 to complete the circuit. The sand settling in cone 11 was run to waste continuously through a bottom valve. The mud collecting in cones 12 was run off through bottom valves intermittently.

The mixer, 18, was steam-jacketed, was divided into two compartments by a partition with openings through it at the bottom and at the height of the top of the steam jacket and was provided with two sets of stirring blades rotating in opposite directions. It was designed to perform several functions. It served as a bitumen reservoir between the separation box, 8, and the settling tank, 20. It maintained the temperature of the bitumen during its travel from the skimming wheel to the settling tank and could heat it further if necessary. The paddles aided transfer of heat from the steam jacket to the bitumen. They also beat down the froth and made the bitumen feed more easily into the bottom part of the settling tank, 20 against the head of bitumen in it.

Settling tank 20 was four feet inside diameter and six feet high exclusive of the cone bottom. It was heated by steam circulating through the jacket at atmospheric pressure.

The dehydrator, 23, was ten feet long by seven feet wide. A steam jacket for high pressure steam extended over the bottom and one foot up the sides. There were three compartments with openings through the partitions at the bottom and one foot above the bottom. Each compartment was stirred by bars of flat iron carried on a pair of chains. The bars scraped the bottom. The dehydrator had sides 18 inches high above the steam jacket to give space for frothing bitumen.

The final settling tank, 25, was six feet wide and six feet high. It was completely surrounded by a steam jacket. Access into the

tank for cleaning out settlings was provided by a manhole, 26. The settled bitumen was drained off into barrels through the pipe and valve, 27.

Steam for heat and power was provided by one 35 h.p. and one 45 h.p. boiler fired with cordwood. Water was pumped from the river by a duplex steam pump to a reservoir standing at the level of the chain conveyor, 1, at the head of the plant. One cylinder of a two cylinder Legerwood hoisting engine of approximately 50 h.p. was used to drive the plant. The exhaust steam from the engine was used for heating plant water.

The steam coils and jackets throughout the plant were fitted with steam traps. A pipe led from each trap to an automatic device which measured the steam condensed. Steam condensed in the high pressure jacket of mixer, 4, was discharged through a trap and pipe into the jacket of mixer 18 and then to the measuring device. The steam coils of separation box 8 and the heating box 13 were connected to one large trap. There were traps also for the coils in the silicate of soda solution reservoir, plant water reservoir, the evaporator and the final settling tank. The steam condensates, after measurement, ran to a barrel from which they were pumped into the steam boilers. Make-up water for the boilers was also measured.

A recording thermometer was fitted to the mixing machine to indicate the temperature at which treated bituminous sand left the machine. Another recording thermometer indicated the temperature of the plant water in the separation box.

A laboratory for analyses of bituminous sand and separated bitumen was set up. The location of the building is shown in Figure 14. Its equipment consisted of a chemical balance and other weighing scales, a battery of distilling flasks and condensers for making water content determinations, an electric muffle furnace for determination of mineral matter contents by ignition, a Dulin Rotarex extractor for determining mineral matter by extraction with organic solvents and an electric oven. Flames for heating distilling flasks were provided by small gasoline blow torches. Electricity for the furnace, oven and extractor was provided by a small generator.

PLANT OPERATION

Separation of bituminous sands was commenced about the first of June and was continued for three months. Approximately 800 tons were put through the plant and 15,000 gallons (75 tons) of bitumen were separated.

The objective of producing a clean, dry bitumen was reached. Whereas the bitumen from former plants had contained from twenty-five to thirty-five percent water and ten percent or more of mineral matter, the finished bitumen from this plant contained less than one percent of water and less than five percent of mineral matter. The improvement was due, of course, to the settling and dehydrating operations. These worked well, considering that the equipment was of the first design tested, and gave good indication that they embodied the correct principle for cleaning the crude bitumen.

The dehydrator was not operated continuously. Sufficient steam pressure to accomplish this could not be applied to it on account of weak construction in the steam jacket. The attempt was made to offset the loss of heating capacity by installing high pressure steam pipes inside the dehydrator between the stirring chains. However, these pipes became coated with mineral matter from the dehydrating bitumen and were soon ineffective. Bitumen was dried in batches, the dehydrator being operated day and night.

The steam jacket of the final settling tank also proved to be weak and it was not safe to maintain the pressure desired. The result was that the final settling was done at from 100° to 110°C instead of at 125°C as planned. A cleaner bitumen would have been produced if it could have been settled in a more fluid state at the higher temperature.

Plain water was used as the separating medium during June and July. During August salt brine was used. This was prepared from a supply of salt secured for the purpose.

Stones in the bituminous sand were a source of trouble throughout the season. These were marcasite and ironstone nodules which occur in the bituminous sand beds with varying frequency. They were particularly plentiful in the Department of Mines quarry. Time was lost daily while nodules were being located in the mixing machine and removed.

The bituminous sand from the quarry displayed disconcerting variability in its behaviour in the plant. Most of it separated well, but some sections of the quarry yielded material that acted badly. It gave a poor yield of bitumen, tarry tailings and turned the plant water black with finely dispersed bitumen. Sometimes an increased amount of silicate of soda treating reagent would overcome the trouble but generally not. It was noted that this sort of material came from sections of the quarry where clay in the bituminous sand was most pronounced and where salt incrustations appeared on the quarry face. The incrustations were due to a mixture of calcium, magnesium, sodium and ferrous sulphates deposited from solution by evaporation. The cause of the variable separation performance was revealed by laboratory work at Edmonton after the close of the season and is discussed in a subsequent section of this report.

DATA FROM PLANT OPERATION

Bituminous Sand.

A sample of about 100 pounds of bituminous sand was accumulated each half day by taking small quantities of material at regular intervals from the feed into the plant. The sample was quartered down to suitable size for water and bitumen content determinations. A summary of the results of bituminous sand analysis is given in Table VI.

TABLE VI.

Average of results of analyses of bituminous sand samples for successive periods of the season. The quarry was deepened as the season advanced.

Date	Average of Analyses		
	% Bitumen	% Water	% Mineral Matter
June 4 to 30	10.5	3.5	86.0
July 8 to 31	12.0	3.5	84.5
August 1 to 12	11.5	3.5	85.0
August 13 to 27	13.5	4.0	82.5

During June the bituminous sand was mined from the surface beds of the quarry. As the season advanced, the quarry was deepened. During the latter part of August the bituminous sand was all taken from the bottom of the pit which finally reached a depth of about eighteen feet. The analyses show that the lower beds of the quarry averaged highest in bitumen content.

Chemical Reagents.

Until salt brine was used, calcium chloride was added to the plant water to coagulate the suspended clay. It was found that it took one-tenth of a pound of calcium chloride for each 100 pounds of bituminous sand under the conditions of running.

The silicate of soda used contained 37% of solids. It was a commercial grade employed by the soap industry. The proportion of this silicate of soda used with the bituminous sand varied widely. Excellent separation performance was secured with less than one pound per ton of bituminous sand. On the other hand five pounds per ton failed to give good performance with some bituminous sand. On account of the variable nature of the bituminous sand throughout the season, no uniformity was attained in the matter of silicate of soda treatment.

Crude Bitumen.

Analyses of bitumen samples taken from the skimming wheel of the separation box showed a wide range of variation. Water contents were from 20% to 35%. Mineral matter contents were from 6% to 15%. Referred to a dry basis, the range would be from 9% to 22%.

Bitumen after First Settling.

While plain water was being used as the separating medium, the settling tank had no effect in cutting down the water content of bitumen passing through it. The mineral matter content was markedly decreased, however. During the first part of a day's run, after the bitumen had been settling in the tank over night, the overflow of bitumen contained about 4% of mineral matter. The mineral content increased during the day, sometimes going as high as 10%.

During July the performance of the settling tank became poorer. When it was cleaned out before starting the use of salt brine it was discovered that the tank was two-thirds full of mineral matter. Although mineral matter had been removed regularly through the

valve at the bottom, material had gradually caked on the cone bottom and around the sides leaving only a steep-sided cone-shaped crater reaching to the valve at the bottom.

On changing to brine plant water (approximately 20% salt) the settling tank gave better results. Provided that the crude bitumen was not stirred in its passage through the mixer between the skimming wheel and the settling tank, overnight settling reduced the water content to between 4% and 6%, and the mineral matter content (exclusive of salt) to 3% or less. During the day while bitumen was being passed through the tank continuously the water content of the bitumen overflow rose steadily. It reached values as high as 25% when the stirring paddles in the small mixer were used. The mineral matter content also increased.

On one occasion, overnight settling reduced the water content to 2% and the mineral matter to 0.5%. At the end of 48 hours settling, the water content was 1% and the mineral matter 0.3%.

While using salt brine for plant water, the mineral matter settling in the tank did not build up on the bottom and sides. There was no difficulty in discharging it through the bottom valve.

Bitumen after Final Settling.

While the final settling tank was being filled for the first time, steam at 90 pounds pressure was used in the evaporator and steam at 10 to 15 pounds was kept in the jacket of the final settling tank. This dehydration and settling produced a final bitumen containing 0.1% of water and from 0.6 to 1.2% mineral matter.

It was necessary, for the sake of safety, to reduce the steam pressure on the evaporator jacket to 30 pounds, and the pressure on the settling tank to little more than atmospheric pressure. The bitumen withdrawn from the final settling tank then showed a water content varying from 0.1 to 1% but generally less than 0.5%. The mineral matter varied between 2% and 6%.

There were only a few periods during which bitumen separated in salt brine was dehydrated and settled by itself. A large quantity of crude bitumen separated in plain water had been accumulated to be dehydrated as there was opportunity, and this was added to the bitumen separated in salt brine to keep the evaporator working day and night. Table VII gives data for three days when bitumen separated in brine only was dehydrated.

TABLE VII.

Analyses of bitumen from final settling tank. Bitumen was separated using 20% brine as plant water.

Date	Analyses of Bitumen					
	% Water		% Mineral Matter and Salt		% Mineral Matter	
	Low	High	Low	High	Low	High
August 15	0.4	0.6	2.1	3.1	1.1	1.4
August 16	0.6	0.7	1.9	2.4	1.0	1.5
August 23	0.0	0.1	2.1	3.6	1.1	1.8

The water content of the final bitumen depended on how long evaporation was carried on. If continued long enough, it could be reduced to zero as happened on August 23rd. The salt water evaporated slowly in the evaporator operated on low pressure steam and it was generally necessary to empty the evaporator into the settling tank while there was still water present (occasionally as much as 1.5%) to make room for fresh bitumen produced by the plant.

Water Requirements of the Plant.

Water was used to make up silicate of soda solution, to replace loss of plant water, for make-up water for the steam boilers, for sluicing tailings out of the plant, for the laboratory and for the camp. Ten gallons per minute was sufficient for all purposes.

Volume of Circulating Plant Water Stream.

It is important that the stream of circulating plant water be sufficient to sweep the feed of treated bituminous sand into the plant readily. An excessively large stream is of no advantage. On the other hand, too small a stream will cause a decrease of separation efficiency. For a feed of $2\frac{1}{2}$ tons of bituminous sand per hour, the volume of water meeting the treated material should be 30 gallons per minute. The circulating pump must deliver this quantity of water and also the sand tailings from $2\frac{1}{2}$ tons of bituminous sand per hour as well as the water run to waste with these tailings. Consequently, the pump should handle about 35 gallons of water and 75 pounds of sand per minute.

Fuel Consumption.

The steam boilers were fired with poplar cordwood—mostly white poplar. The boilers were housed in a board building but were not insulated otherwise against loss of heat. The boilers used $1\frac{1}{2}$ cords of wood during the 10 hours of the day during which separation was carried on and another $1\frac{1}{2}$ cords during the balance of the 24 hours for keeping the plant water warm, evaporating bitumen and running a small engine for driving the electric generator.

Steam Consumption.

The evaporation of water from the steam boilers for various conditions of running the plant is given in Table VIII. The use of steam as allotted to the separate parts of the plant is reported in pounds per hour. The figures are averages for a number of days of similar running. They were obtained by measuring the quantities of condensate which were formed in the various steam coils and jackets.

The make-up water corresponded to steam that escaped. All the exhaust steam from the engine driving the plant was not always used in heating. When the generator engine was running in addition to the main engine, its exhaust escaped. When running alone at night, its exhaust was turned into the heating coils of the plant. Steam to the duplex steam pump on the river bank escaped. Steam to both the settling tanks escaped. One was heated with steam at

atmospheric pressure. There was too little pressure on the other to lift the condensate to the height of the measuring device.

The condensate from the steam jacket and high pressure steam coils of the evaporator was measured. But as the evaporator did not keep pace with the separation of bitumen by the plant, figures do not appear in the table for the evaporator. The condensate from the evaporator averaged 235 pounds per hour while plain water was used as the separation medium and 150 pounds per hour while salt brine was used.

The plant made its best showing while salt brine was used as plant water. Bituminous sand was separated at the rate of 2.4 tons per hour with a steam consumption of 1047 pounds per hour for all purposes associated with the running of the plant excepting evaporation of water from the bitumen. This corresponds to the use of 437 pounds of steam per ton of bituminous sand separated.

TABLE VIII.
STEAM CONSUMPTION OF PLANT
Pounds of steam per hour

	1	2	3	4	5	6	7
Mixing Machine	173	172	183	153	32	3	2
Separation Box and Circuit	189	164	173	157	200	66	46
Plant Water Reservoir	64	40	43	46	32	25	17
Silicate Solution Tank	40	36	37	36	38	16	15
Make-up Water	466	602	726	655	470	300	180
Total Separation and Settling	932	1014	1162	1047	772	410	260

1. Average for 5 days in June. Stops and interruptions included. Plain water used as separation medium.
2. Average for 6 days in July. Noon hour not included. Plain water used as separation medium. Throughput of plant averaged 1.8 tons per hour.
3. Average for 9 days in July. Readings on which calculations were made extended only over time when plant was separating steadily. Plain water used as separation medium. Throughput of plant on same basis averaged 2.2 tons per hour.
4. Average for 9 days in August. Reading on which calculations were made extended only over time during which the plant was separating steadily. Salt brine of 20% concentration used as separation medium. Throughput of plant on same time basis averaged 2.4 tons per hour.
5. Average for 5 hours during which the plant was run in every respect as when separating bituminous sand but no sand was fed into the plant.
6. Average for 5 nights. An engine was run to drive the generator part of the night. The plant water was kept warm and was brought up to proper temperature for starting separation in the morning.
7. Sundays.

There is no doubt but that work on a larger scale could be carried out more efficiently. It took 772 pounds of steam per hour to run the plant as for separation but without putting any bituminous sand through. Consequently the steam required to separate sand at the rate of 2.4 tons per hour over and above that needed to simply turn over the machinery, pump water, keep the plant water and mixing machine hot, and generate electricity needed for the laboratory was 275 pounds per hour. Assuming that the throughput of the plant could be increased to 5 tons per hour without materially increasing plant dimensions, the total steam consumption for separation at the rate of 5 tons per hour would be 1350 pounds per

hour. This would correspond to 270 pounds of steam per ton of bituminous sand separated.

Labor.

The crew used to operate the plant was as follows:

- 1 millwright who was also foreman,
- 1 engineer,
- 1 laborer supplying engineer with wood,
- 2 laborers feeding bituminous sand into plant,
- 2 operators watching and regulating the plant,
- 2 technicians collecting and analysing samples.

A second engineer was used to tend the boilers during the night and to have the plant in readiness for separation work each morning.

The same size of crew could operate a plant of 50 tons per hour capacity. Two mechanics for repair work would be needed, however.

Estimated Cost of Separation.

An estimate of the cost of separating bituminous sand on a commercial scale was published in a previous report.* Excluding estimated mining costs, the figure arrived at was \$4.20 per ton of separated bitumen. In making the estimate it was assumed that a plant of 50 tons per hour capacity costing \$200,000 would be used and operated 200 days of the year on bituminous sand which would yield one ton of bitumen per seven tons treated. Interest on investment and depreciation were placed at 8% and 20% respectively. A cost of 45 cents for generating 1000 pounds of steam was assumed. The relative magnitude of the various cost items were as follows:

Interest	15%
Depreciation	35%
Supervision and labor	15%
Heat and power	25%
Chemicals	10%

Plant operations during 1930 indicated that the requirements for supervision and labor, heat and power and treating reagents used in the estimate were essentially correct. Detailed design of a separation plant at a specific site must be prepared before further consideration of the cost of a commercial separation plant can be made.

Investigation of Refractory Bituminous Sand.

The unexpected difficulty of freshly mined bituminous sand that separated badly called for an explanation. Several observations were made which seemed likely to be of significance. It was noted that when refractory sand was being fed into the plant, the plant water became acid. Determination of the hydrogen ion concentration in the plant water would show about pH 5. Bituminous sand from the quarry was examined by stirring samples in twice their volume of water and determining the hydrogen ion concentration of the water. Refractory sand gave pH 5, while sand that separated readily was less acid as it gave pH 6. Water that collected in the

*The Bituminous Sands of Northern Alberta. Part II. K. A. Clark and S. M. Blair. Research Council of Alberta, 1927, p. 29.

bottom of the quarry after a rain gave pH 5. A solution of some of the salts which appeared on the quarry face was even more acid and gave pH 4.

A supply of four grades of bituminous sand was collected and shipped to the laboratory at Edmonton for examination. One was sand that separated readily in the plant; the second was material that gave some trouble; the third was clayey bituminous sand that acted very badly; and the fourth was lumpy material that had been thrown aside on the storage platform because it gave trouble in the plant. Samples of clay both from the overburden of the quarry and from clay masses in the bituminous beds were also sent to Edmonton. In addition, a barrel of bituminous sand from the International Bitumen Co. quarry was secured. This quarry is on the east bank of the Athabaska river about fifty miles below McMurray. The sand from it was being separated readily without use of treating reagent in a simple hot water separation plant.

TABLE IX.

Composition and sieve analyses of bituminous sands used in investigation of cause of refractory behaviour of bituminous sand at separation plant. The percent of soluble material that can be extracted from the bituminous sands with water and the pH value of 200 ccs. of water in which 150 grammes of bituminous sand has been stirred are also shown in the table.

Sample No.	Composition of Samples			Screen Analyses of Mineral Matter					Water Soluble %	pH
	% Water	% Bitumen	% Mineral Matter	Retained on Mesh				Passing Mesh 200 %		
				28 %	48 %	100 %	200 %			
1	0.7	10.4	88.9	14	16	52	15	3	0.15	2.5
2	0.3	11.9	87.8	10	19	54	14	3	0.12	2.5
3	0.6	8.6	90.8	4	10	51	20	15	0.45	2.5
4	0.6	10.0	89.4		2	13	74	11	0.11	2.7
5	1.0	13.5	85.5		58	39	2	1	0.02	5.7

- Sample 1. Department of Mines quarry on Clearwater river. This material separated quite well in the plant.
- Sample 2. Department of Mines quarry. This material separated fairly well.
- Sample 3. Department of Mines quarry. This material acted very badly.
- Sample 4. Department of Mines quarry. Hard, lumpy material that separated poorly.
- Sample 5. International Bitumen Co. quarry, Athabaska river. This material separates with remarkable ease.

An analysis of a sample from each of these five supplies of material is shown in Table IX. The material in each supply was fairly uniform except in the case of No. 4. This was made up of a heterogeneous collection of lumps. The water contents of the bituminous sand when analysed were much lower than those found in freshly mined material (cf Table VI). When these samples were examined at Edmonton they imparted a pH value of 2.5 to water in which they were stirred whereas similar material tested in the north fresh from the quarry gave pH 5. The analysis of the bituminous sand from the International Bitumen Co. quarry is interesting in comparison with the sands from the Department of Mines quarry. It contained a coarser sand, very little mineral matter passing the 200 mesh sieve, very little water soluble salts and imparted less acidity to water in which it was stirred.

TABLE X.

Results of laboratory separation tests on bituminous sand described in Table IX. Material was treated with the same grade of silicate of soda used in the northern plant. It contained 37% solids. Separation medium was a 20% salt brine. The separated bitumen was collected in a beaker and placed in a hot water bath for one hour to allow salt brine to settle. 7700 grams of bituminous sand were used for each separation run. Sufficient water was added in the treatment to give the heated and treated bituminous sand the right consistency for feeding into the plant.

Sample No.	Reagents % of weight of Bitu- minous Sand treated		Composition of Separated Bitumen			
	Silicate of Soda	Water	% Water	% Mineral Matter	% Salt	% Bitumen
1	0.55	24	11.2	7.9	3.0	77.9
2	0.55	24	14.1	7.5	4.0	74.4
3	0.55	24	37.5	20.9	10.1	31.5
4	0.55	29	11.9	10.4	3.4	74.3
5	0.15	8	3.1	2.3	1.5	93.1
5	0	8	6.6	2.8	4.1	86.6

The results of laboratory separation tests on the five samples of bituminous sand are given in Table X. In spite of treatment with a comparatively high percentage of silicate of soda and the thorough mixing secured in the laboratory mixing and heating machine, separation results were poor in the case of all the samples from the Department of Mines quarry. On the other hand, the material from the International Bitumen Co. quarry gave good separation results with a low percentage of silicate of soda and even with no reagent at all.

Observation during the season in the north led to the belief that the cause of the trouble with the bituminous sand from the Department of Mines quarry was due to the presence of soluble salts and to clay. Consequently it was considered that if the salts and clay were removed by washing in cold water before separation a decided improvement in results would be found. To test this theory a quantity of bituminous sand from each supply brought to the laboratory was washed thoroughly. No difficulty was experienced in washing materials from supplies 1, 2 and 3. The bituminous sand broke up in the water, did not stick to the washing apparatus and a considerable showing of clay passed off with the wash water. Supply 4 was hard lumpy material that could not be broken up in cold water. Consequently warm water was used. The washing removed very little clay from this batch. When material from supply No. 5 was stirred in cold water the bitumen drew away from the sand and became a mass of clean sand and bitumen clots.

The results of the separation tests on washed bituminous sand are shown in Table XI. A low percentage of silicate of soda was used in the treatment as it was thought the washing would make this sufficient. The results were far from satisfactory.

The high pH values obtained by stirring the bituminous sand from the International Bitumen Co. quarry in water as compared to the low values for bituminous sand from the Department of Mines quarry and the better separation performance of the former material led to the idea of adjusting the pH value of the latter material by addition of sodium hydroxide. A series of separation

TABLE XI.

Results of laboratory separation tests on bituminous sand described in Table IX which had been thoroughly washed in cold water to remove soluble salts and clay. Otherwise, the separation procedure was the same as stated in Table X.

Sample No.	Reagents % of weight of Bituminous Sand Treated		Composition of Separated Bitumen.			
	Silicate of Soda	Water	% Water	% Mineral Matter	% Salt	% Bitumen
1	0.15	21	9.3	13.4	2.9	74.4
2	0.15	26	10.0	11.9	2.8	75.2
3	0.15	26	17.8	10.4	5.5	66.3
4*	0.15	24	12.6	10.6	3.3	73.5

*110ccs. kerosene was added to the hard lumpy bituminous sand separated in this run.

TABLE XII.

Results of laboratory separation tests on bituminous sand described in Table IX. The material was treated with sodium hydroxide and with silicate of soda containing 37% solids. After addition of either reagent to the charge being treated, 150 gms. of the charge were stirred in 200 ccs. of distilled water and the pH value of the water determined. The separation medium was 20% salt brine. The separated bitumen was allowed to settle in a hot water bath for one hour after being collected.

Sample No.	Treatment Reagents (% of weight of Bituminous Sand Treated)					Composition of Separated Bitumen			
	Sodium Hydroxide		Silicate of Soda		Water %	% Water	% Mineral Matter	% Salt	% Bitumen
	%	pH	%	pH					
1	0.026		0.15	5.2	18	11.6	5.4	3.2	79.8
1	0.026		0.30	5.4	18	11.7	4.1	2.8	81.4
1	0.026	5.4	0.00	....	18	14.5	3.6	4.5	77.4
1	0.052	5.4	0.15	6.0	18	10.0	3.0	2.8	84.2
1	0.078	6.2	0.15	6.3	18	6.7	2.9	2.1	88.3
1	0.065	6.2	0.15	6.4	18	8.4	2.5	2.4	86.7
1	0.091	6.4	.....	....	18	9.2	1.7	2.8	86.3
1	0.091	6.4	0.15	6.4	18	6.6	0.7	1.1	91.6
1	0.120	6.4	0.15	6.4	16	6.7	0.9	0.5	91.9
1	0.140	6.8	.....	....	18	8.9	1.6	1.2	88.3
1	0.091	6.4	0.30	9.0	18	11.9	1.0	1.8	85.3
1 washed	0.091	6.2	0.15	8.2	16	12.5	0.8	0.9	85.8
2	0.065	4.7	0.15	4.7	18	11.6	4.1	1.9	81.4
2	0.091	6.0	0.30	6.2	23	9.3	2.4	2.2	86.1
2	0.091	6.2	0.15	6.2	23	9.9	3.2	2.4	84.5
2	0.260	6.4	0.15	6.4	16	7.6	3.1	1.5	87.8
2	0.260	6.7	0.15	6.7	13	7.4	2.2	1.6	88.8
2	0.380	6.7	0.30	9.1	12	7.2	1.6	1.1	90.1
2 washed	0.091	6.4	0.15	7.5	16	11.0	0.7	0.6	87.7
3	0.117	3.5	0.30	3.5	23	20.4	8.3	5.0	66.3
3	0.520	6.7	0.30	9.1	12	(Bitumen all dispersed in plant water)			
3 washed	0.170	6.4	0.15	6.4	21	5.9	2.7	1.0	91.4
3 washed	0.170	6.8	0.15	9.0	26	12.3	0.7	0.7	86.3
3 washed	0.195	7.8	0.15	9.0	23	10.1	0.8	0.7	88.4
4	0.078	6.3	0.30	6.4	26	10.0	4.1	0.7	85.2
4	0.156	6.4	0.15	6.4	23	6.4	2.3	1.1	90.2
4	0.169	6.8	0.15	8.8	23	17.2	2.2	0.5	80.1
4	0.156	6.3	0.30	9.0+	26	14.6	3.0	1.3	91.1
4	.....	....	1.10	9.3	23	11.0	2.6	0.5	85.9
4	0.143	9.4	.....	....	29	16.7	3.1	1.8	78.4
4	0.182	6.8	0.30	9.6	22	16.5	1.6	1.1	80.8
4	0.182	9.0	0.30	10.0	23	12.2	2.7	0.9	85.1

tests were run in which sodium hydroxide was first added in the treatment followed, in most cases, by addition of silicate of soda. The results of this series of tests are given in Table XII.

The effect of increasing the pH of the bituminous sand by addition of sodium hydroxide was striking. The mineral matter content of the separated bitumen decreased as the pH value rose. When this value was 6.4 or greater, the mineral matter content was almost always small and in the case of samples 1, 2 and 3 consisted of silt or clay almost entirely.

The figures in Table XII seem to indicate that the function of the treating reagent is to neutralize the acidity of the bituminous sand. It does not seem to matter whether this is done by sodium hydroxide alone, by a combination of sodium hydroxide and silicate of soda or by silicate of soda alone. Silicate of soda may have an effect distinct from that of sodium hydroxide, however. There is some indication that it causes a difference in the physical nature of the separated bitumen. Further investigation is necessary to determine whether there is real advantage in the use of silicate of soda. It may be found that any reagent which will neutralize the acidity of the bituminous sand is a satisfactory treating reagent.

Washing the bituminous sand in cold water before separation appears to be advantageous in the case of a refractory sand. Table XII shows that with samples 2 and 3, less treating reagents is required to neutralize the washed than the unwashed sand. Separation results also are particularly good with the washed material.

Sample 3 was a clayey bituminous sand, as can be seen from its analysis in Table IX. Neutralizing it before separation did not give a good result. Practically no bitumen collected on the surface of the separation box. It seemed to have all dispersed in the plant water. This bituminous sand, when washed before separation, gave good results. Consequently it would appear that the presence of clay in quantity is a bad feature quite apart from its soluble salt content. It seems to cause emulsification of bitumen in the plant water and reduction of yield.

The quantities and compositions of the water-soluble material present in the bituminous sand from the Department of Mines quarry and in the clay found as partings and as sizable masses in this bituminous sand and also in the clayey material which forms the overburden over the bituminous sand beds are indicated in Table XIII. Similar data for a mixture of bituminous sand and salt incrustation scraped from the face of the quarry and for a sample of bituminous sand from the quarry of the International Bitumen Company are included in the table. Approximately 250 grams of sample were stirred in about 900 cc. of distilled water at 85°C for 15 minutes and then filtered. The filtrates obtained in this way were submitted to the provincial analyst and the figures in Table XIII have been calculated from the water analyses reports, and the known weights of samples extracted and filtrates obtained.

The presence of free sulphuric acid in the filtrates from extraction of the samples is interesting. Presumably this acid is derived mainly from hydrolysis of iron salts. The greater acidity of the

bituminous sand brought to the laboratory at Edmonton than that observed with similar material tested directly after being taken from the quarry suggests that free acid is liberated in the bituminous sand after mining when iron salts are present.

TABLE XIII.

Quantity and composition of soluble material extracted from samples of clay and salt incrustations associated with bituminous sand beds and from bituminous sand samples. Samples were stirred in water at 85°C for 15 minutes, filtered and the filtrates submitted for water analyses.

Sample No.	1	2	3	4	5	6	7	8	9	10	11	12	13
Percent Extracted	0.6	20.0	0.8	2.4	0.15	0.06	0.12	0.08	0.42	0.08	0.11	0.04	0.02
Composition of Extract:													
Ferrous Sulphate %	35.5	7.0	27.2	39.4	26.5	18.5	33.0	37.5	26.0	54.0	36.0		
Ferrie "	1.0	55.5	2.6	1.1			5.0	6.5	16.5	5.0		7.0	6.0
Aluminum "		11.5	4.6	11.6									
Calcium "	36.0	6.5	26.1	20.2	38.0	37.5	1.0	18.5	17.0	11.5	13.0	53.0	88.0
Magnesium "	10.5	0.5	13.4	12.2					9.0				
Sodium "	6.5	14.0	13.4	8.6	6.5	14.0	12.5	6.5	1.5	5.0	9.0	13.5	
Sodium Chloride	2.0	1.0	2.7	1.1	2.5	4.5	2.5	3.0	1.0	2.5	2.0	7.0	6.0
Sulphuric Acid	8.5	4.0	10.0	5.8	26.5	25.5	46.0	20.0	29.0	22.0	40.0		

- Sample 1—Bands of clay in the bituminous sand beds.
 " 2—Mixture of salt incrustation and bituminous sand from quarry face.
 " 3—Clay occurring in masses in the bituminous sand beds.
 " 4—Clay from overburden.
 " 5—Bituminous sand which separated readily at northern plant (cf Table IX).
 " 6—Sample 5 washed thoroughly in cold water before extraction.
 " 7—Bituminous sand which separated fairly readily (cf Table IX).
 " 8—Sample 7 washed thoroughly in cold water before extraction.
 " 9—Clayey bituminous sand which separated badly (cf Table IX).
 " 10—Sample 9 washed thoroughly in cold water before extraction.
 " 11—Lumpy, hard bituminous sand which gave trouble in separation (cf Table IX).
 " 12—Sample 11 washed in warm water before extraction.
 " 13—Bituminous sand from the International Bitumen Co. quarry (cf Table IX).

Conclusion.

The completion of the two year program of development has resulted in notable advances in bituminous sand separation. A separation plant has been built and successfully operated in the north country at the deposits. This has had psychological as well as technical value and has probably done as much to direct public interest to Alberta's bituminous sand resources as all the previous studies at Edmonton. The separation procedure has been completed by the addition of operations which remove water and sand from the crude separated bitumen and yield a clean product. Former plants performed the essential separation, but produced a bitumen containing too much water and sand to be of much practical value. The northern plant, however, produced a bitumen which was comparatively free from these impurities and which was used as commercial asphalts are used for preparing pre-mixed highway surfacing aggregate by standard equipment. Finally out of difficulties encountered with the northern plant has come knowledge of outstanding practical importance regarding the factors on which separation efficiency depends. Discovery of the bearing of acidity of bituminous sand on separation and the real function of treating reagents will likely prove to be the most valuable result of the project.

Several suggestions for the guidance of future development work follow from the experience of operating the northern plant. In the first place, provision should be made for either catching and eliminating or crushing ironstone nodules in the bituminous sand. The sand cannot be properly mixed with treating reagent if stones are present.

The soluble salts and clay which occur in the bituminous sand beds interfere with the separation process. If these are present in small quantities their effect can be offset by treating reagents. But some beds contain sufficient amounts of these substances to make correction by reagents impossible. The best solution of the difficulty is probably to wash the bituminous sand in cold water before introducing it into the separation plant. Decrease in the quantity of treating reagent required and increase in yield of bitumen should repay the cost of the operation even when the operation is not essential for carrying out the separation.

Special attention should be directed, in future development work, to determining the best type of mixing equipment for heating the bituminous sand and treating it with reagent solution. The preparation of the material for separation is the key operation of the process and too much importance cannot be placed upon it.

The general scheme of separation in salt brine, settling of brine from the crude bitumen, evaporation of retained water and final settling at increased temperature appears to be a satisfactory one for eliminating water and sand from the crude separated bitumen. The settling and dehydrating equipment used at the northern plant can be improved upon, however. Continuous settling of the brine from the crude bitumen was not very successful. It would be better to do this settling as a batch operation. Also the type of dehydrator used was not a good one. A pipe still operated under pressure and an expansion chamber should be more suitable.

Study of the effect of acidity and the presence of soluble salts, clay and other finely divided material on separation is being continued in the laboratory. Determination of the asphalt products which can be prepared from the separated bitumen and their physical properties is being planned.

SOIL SURVEYS

BY F. A. WYATT

Three parties were engaged in soil surveys during the summer. The area covered by each party is indicated as follows:

Area between Fort Vermilion, Keg River post and Hay River post.

Field party in charge of O. R. Younge. The area covered by this party extends from R. 11, W. of 5th to the 6th Meridian, and lies between the Keg-Peace rivers and Ray river-Roe creek-Caribou Mountains. The area comprises about 3,500,000 acres. The parkland (11,000 acres) and first-class wooded soils lying chiefly about the lower Boyer river, constitute about 390,000 acres. Of this amount some 20,000 acres are already occupied, leaving approximately 2,300 quarter sections yet to be settled. These two classes consist of soils which, without a doubt, are sufficiently fertile to insure satisfactory crop returns. This area is from 5 to 30 per cent open prairie, with the remainder medium to heavy clearing of 3 to 14 inch aspen. Cost of clearing will average \$10.00 to \$20.00 per acre. Less than 5 per cent of the area is muskeg and about 1 to 2 per cent is hay meadow. Sufficient water supplies are encountered at 20 to 40 foot depths. Surface waters, excepting the Boyer river, are restricted to a few swampy lakes and sloughs. The topography is such that it could be easily cultivated, hence roads are readily constructed within the area.

In addition to the above two classes there are 2,900,000 acres of second class wooded soils. These soils are separated from the Peace river by an 8 to 20 mile strip of first and third class wooded soils. It is estimated that approximately 20 per cent of the second class wooded soil areas is muskeg and swamp. These areas are not occupied and therefore contain some 12,700 quarters of land available for settlement, excluding the muskegs. The topography is chiefly level and gently undulating. Road construction presents no serious difficulties. The bulk of these areas is heavily wooded or is being restocked with aspen, willow and some spruce. Cost of clearing varies widely being from \$10.00 to \$60.00 per acre, with an average of between \$20.00 and \$30.00 per acre. Pasturage is fairly plentiful during 4 to 5 months of the year. In some localities considerable wild hay can be harvested, yet these resources will satisfy only limited local needs. Surface waters are inadequate or entirely wanting over the larger portions of the second class wooded area, except for a few streams and lakes.

The second class wooded soils should be settled only after areas of similar soils closer to railway facilities have been utilized, and then only after railway or other transportation facilities have been provided.

Included in the surveyed area are some 570,000 acres of third class wooded soils. About 70 to 95% of these areas are muskeg,

which usually carry a stunted, sparse covering of spruce and some tamarack. The balance is composed of infertile jackpine ridges and mountains. These areas have no agricultural value at the present time and should therefore be set aside as forest and game reserves.

Area between Peace River and Fort Vermilion.

J. L. Doughty had charge of this field party. The area covered extends from Peace River to Fort Vermilion, and lies between the Peace river and a line drawn from Cadotte lake to the western extremity of the Buffalo Head hills and thence northeast to Fort Vermilion. The area as outlined comprises about 2,995,000 acres. Parkland and first class wooded soils constitute about 94,000 acres. About 24,000 acres of first class wooded soils, situated near Peace River, are already occupied. The remaining 70,000 acres of fertile soils extend from the Buffalo Head hills to Fort Vermilion. Probably half of this area is occupied, leaving approximately 200 quarter sections suitable for settlement. There seems to be no water problem for the area between Carcajou and Ft. Vermilion. Although surface waters are scarce or consist only of sloughs and lakes, numerous small streams indicate a fairly adequate supply. Pasturage is plentiful and considerable wild hay may be harvested, although it is not abundant. About 10 to 30 per cent of the area is open prairie, the remainder being covered with 2 to 14 inch aspen and willow. Cost of clearing will be approximately \$10.00 to \$20.00 per acre. Although much of the land comprising this area is settled, only a relatively small amount is cultivated.

In addition to the above two classes of soils there are 98,000 acres of second class wooded soils, of which 12,000 acres are situated near Peace River and are already occupied. The remaining 86,000 acres (540 quarters) are chiefly situated northeast from Carcajou Point. These lands have either been subjected to severe fires or are covered with medium to heavy clearing of aspen, willow and spruce. Estimated cost of clearing is \$10.00 to \$30.00 per acre. Pasturage is fairly plentiful in the open beaver meadows and on the burns where vetch and peavine occur.

In addition to the above classes of soils there are 2,804,000 acres of lands which are considered infertile or otherwise unsuited for agricultural purposes other than as game and forest reserves. The bulk of this area is to be found lying between Cadotte lake and Carcajou Point. This area lacks drainage and is estimated to be 50 to 90 per cent muskeg and swamp. The low ridges which occur are sandy, stony, and badly burned, or they have suffered excessive leaching. Where the soil permits, the area is heavily timbered with a mixed aspen and spruce growth.

Area between High Prairie and Bezanson.

A. S. Ward had charge of this field party. The area covered extends from Range 17, West of 5th Meridian, to the Smoky river, and lying between Township 69 and Township 75. The area as outlined comprises 1,756,160 acres. The topography as a whole is almost level, excepting a few minor elevations. As a result roads can be readily constructed in any desired direction. Some good stands of merchantable timber are to be found in Townships 72 and

73, Ranges 18 and 19, and again in Townships 72 to 74, Ranges 23 and 24, West of 5th Meridian. Exclusive of the above mentioned timber areas the bulk of the area is heavily timbered with aspen and spruce.

Second class parkland soils constitute 18,880 acres, and first class wooded soils represent 140,000 acres. Approximately 100,000 acres are not occupied, thus leaving some 625 quarters of fertile lands suitable for settlement. Most of the unsettled area is covered with a heavy stand of timber, only 5 to 15 per cent being open prairie. Cost of clearing is estimated at \$15.00 to \$40.00 per acre, the bulk being cleared at \$20.00 to \$25.00 per acre.

In addition to the above two soil classes, there are 1,300,000 acres of second class wooded soils. About 25,000 acres have been settled, the remainder (7,900 quarters) being as yet unoccupied. The second class wooded soils represent about five-sixths of the surveyed area. The topography is too level over a large portion of the area for good drainage, hence much spring flooding results. Pasturage and wild hay meadows may be found throughout the area. Surface waters are adequate at present, but will undoubtedly be found wanting following more fires and increased settlement. The covering is chiefly heavy clearing of mixed aspen and spruce. Cost of clearing is estimated to average \$20.00 to \$35.00 per acre. In view of the proximity to existing railway facilities, the whole surveyed area, excluding submarginal lands, should be settled before areas of a similar nature farther removed from transportation.

Besides the soil classes already mentioned there are 128,000 acres of third class wooded soils, 113,900 acres of eroded lands and 71,500 acres of muskeg and lake. The bulk of the third class wooded soils is infertile or of too rough topography to be of agricultural value. They will, however, have some value as forest reserves and should be set aside for that purpose. Much of the area either carries commercial timber or is restocking.

A brief summary covering the soil classification of the three surveyed areas is presented as follows:

Class.		Area (acres)	Percentage
Second class parkland	(A2).....	46,000	0.6
First class wooded	(W1).....	610,000	7.4
Second class wooded	(W2).....	3,400,000	41.3
Third class wooded	(W3).....	3,500,000	42.2
Eroded	(E).....	114,000	1.4
Muskeg	(M).....	551,000	6.7
Lake	(L).....	31,000	0.4
Total area	.....	8,252,000	100.0

NATURAL GAS RESEARCH

BY E. H. BOOMER

The following brief report summarizes the results of the three divisions of this work during the calendar year 1930. The project was divided into three major parts in 1929, namely: hydrogenation of coal and tar, water gas and its reactions, the pyrolysis of natural gas. All are still in progress and two of them, the first and third, show some promise. The third in fact appears to be reaching the stage where large scale testing will be warranted.

Three full time assistants have been employed continuously and, during four summer months, a fourth assistant was engaged on routine analytical work. Financial support was furnished by the National Research Council of Canada acting equally with the Research Council of Alberta.

A detailed account of each part of this project will appear in theses submitted to the University of Alberta by the assistants concerned. Copies will be available for inspection at the University Library after May, 1931.

It should be mentioned that research on the chemical utilization of natural gas has been commenced in the National Research Council laboratories in Ottawa. This work is allied to work of the division on pyrolysis and has as its primary object the production of unsaturated hydrocarbons by pyrolysis of natural gas. Particular attention is being given to hydrocarbons higher than methane such as propane and butane. No work along these lines has therefore been done in Edmonton.

Hydrogenation.

This work was carried out with the assistance of A. W. Saddington.

Alberta's coal fields, bituminous sand deposits and natural gas resources represent three of the world's important supplies of carbonaceous materials. Development of these is at present confined to a few coal producing areas and to three gas fields. Among the gas fields being exploited is the Turner Valley area which produces a "wet" gas containing a relatively small amount of naphtha. These gases are stripped of their naphtha content and the remaining dry gas, largely methane, is for the greater part destroyed by burning in the field. Thus, some 60,000 cubic feet of gas are destroyed for each barrel of naphtha recovered. About 75,000,000 cubic feet of gas are used daily in the neighboring cities, but this is not more than one-eighth of the total gas available. Apart from the Turner Valley field there are in the province many dry gas wells, at present capped and conserved, awaiting utilization. In 1926 the possible daily production of these dry gas fields was in excess of 400,000,000 cubic feet.

In view of the availability of cheap and adequate sources of the necessary raw materials an investigation of a process of liquefaction by hydrogenation of Fort McMurray bitumen was initiated in the summer of 1929. From an industrial point of view the processes of hydrogenation of carbonaceous materials depend for success on a sufficient and cheap source of hydrogen. The commercial production of hydrogen from natural gas has been shown to offer no great experimental difficulties.

This division of the project has been restricted to the hydrogenation of McMurray bitumen. Since the last report appeared, a larger autoclave has been installed and used exclusively on this work. This autoclave is of approximately 2 litres capacity and allows of thorough agitation and uniform temperature control of its contents. Mechanical troubles with the metallic gaskets, due to high temperatures and to the corrosive action of sulphur in the bitumen, have delayed this work. The trouble has been such as to delay completion of the work on bitumen in this autoclave to the present time.

The first experiments were carried out on 1200 gram samples of bitumen and such charges were found to be unsatisfactory in leaving too small a volume for the gas phase and in thus delaying hydrogenation. These experiments showed, however, a great improvement over the results obtained with the original small autoclave. At 400°C coke formation was slight, or absent altogether, as compared with 10% to 20% produced previously. The gasoline yield, however, was lower, averaging about 25% of the autoclave oil. Smaller quantities of bitumen, 700 grams and 900 grams, were used in succeeding work. They were more satisfactory in allowing very rapid hydrogenation and producing a lower maximum pressure. The coke formation appears to be less. A series of experiments using ammonium molybdate as catalyst showed little improvement over those experiments without added catalysts. It is considered hardly worth while to use a catalyst with bitumen. Ammonia is known to have a catalytic effect, even in the absence of molybdenum, and the nitrogen compounds of bitumen yield ammonia by hydrogenation.

The gasoline yield from the autoclave oil increases with rising temperature, reaching 50% at 450°C, but the coke production increases simultaneously to 20%. The gasoline yield after refining amounts to 35% to 40% of the original bitumen. These gasoline yields are minimum values. In nearly all the experiments an exact balance between the weight of bitumen and the weight of products is not obtained. There are two major sources of loss, failure to collect all of the oil and coke produced, and evaporation losses from the oil. This latter loss is the greater of the two and consists of the more volatile portions of the oil. Some 2% to 3% of volatile products boiling from 30°C to 50°C can be condensed from the gas produced in the autoclave. The results of typical experiments are shown in Table XIV.

Experiments 60 and 61 used ammonium molybdate as catalyst. Experiment 72 was on the hydrogenation of a pitch residue and 87 and 88 were on oil residues. In experiments 60 to 74 inclusive,

three or more successive hydrogenations were carried out on the autoclave charge. The rate and amount of hydrogen absorption decreased with each successive run and the total hydrogen absorbed is not greatly in excess of that absorbed in the initial run. It is apparent that 400°C to 425°C is the best temperature range in these batch experiments. The autoclave should not be more than half full in order that hydrogen be available in sufficient quantity. The residual oil after removal of the gasoline from the autoclave oil may be hydrogenated with further production of gasoline. Experiments 87 and 88 were carried out on such oil. The autoclave oils produced in 87 and 88 show smaller gasoline yields but no coke formation. They are of interest in containing a large fraction of heat stable lubricating oil stock. Experiment 72 was carried out on a soft pitch residue yielded by autoclave oil after vacuum distillation to 250°C. The gasoline yield is low and the residual oil is quite fluid. It would serve as a cracking stock or fuel oil. This residual product, the end of two hydrogenations and distillations, amounts to one-sixth of the original bitumen. It could be treated further with hydrogen at higher temperatures and reduced to gasoline and coke, but for practical purposes this residue may be considered a final product and good only for cracking or fuel.

TABLE XIV—HYDROGENATION OF BITUMEN

Experiment Number	60	61	68	72	73	74	83	85	86	87	88
Charge, grams	1200	1200	900	1200	900	915	910	710	710	925	725
Temperature, °C.	380	400	400	400	425	425	445	440	425	420	450
Initial pressure of hydrogen, lbs. per sq. inch	1460	1460	1040	1160	1290	1160	1000	1000	1000	1000	1000
Time, hours	18	10	14	14	10	8	1	2	3	3	3
Oil as percent of bitumen	91.4	90.5	94.6	92.0	74.5	72.2	58.4	63.5	76.2	86.3	73.9
Coke as percent of bitumen	0.0	0.0	0.0	2.8	12.8	10.4	21.8	18.4	12.0	0.0	0.0
Gas as percent of bitumen	1.7	1.6	2.4	1.7	3.3	7.0	3.4	4.9	4.5	2.0	4.8
Loss as percent of bitumen.....	6.9	7.9	3.0	3.5	0.0	10.4	16.4	13.2	7.3	11.7	21.3
Gas yield, litres per kg. bitumen	36.4	33.2	54.3	37.1	67.0	106.5	66.5	87.3	77.3	37.6	85.0
Hydrogen absorbed, percent by weight	1.3	1.1	1.5	1.0	1.3	1.4	0.5	0.8	1.0	0.5	0.6
Gasoline in oil—A.S.T.M. dis- tillation—%	20.0	20.0	20.0	11.0	31.0	47.0	49.0	49.0	38.0	17.0	21.0
End point of distillation, °C.....	310	318	363	335	343	338	340	342	314	343	357
Pitch in oil, %	59	59	34	41	37	24	24	19	27	36	41
Refined gasoline, based on bitumen, %	11.6	13.0	13.9	.....	17.9	28.2	23.4	25.6	25.1	.....	.....

NOTES: The charge in experiment 72 was a soft pitch residue, and in experiments 87 and 88 was oil residues. In all other experiments the charge was bitumen. In experiments 60–74 inclusive three or more successive hydrogenations were made on the same charge.

In experiments 60 and 61 ammonium molybdate was added as catalyst.

These experiments on residual oils after gasoline distillation indicate the possibilities of continuous hydrogenation and distillation. Conversion in one operation of 80% to 85% of the bitumen to gasoline, without coke formation, appears probable. A larger autoclave designed for this purpose is in construction.

In this connection, a number of experiments were performed at 425°C on 900 gm. charges of bitumen in which the hydrogen was diluted with Viking gas. These experiments had for their object the determination of the minimum hydrogen concentration at which hydrogenation would proceed satisfactorily. It was found the hydrogenation became appreciable only at hydrogen concentrations

above 50% by volume and satisfactory performance is only possible at concentrations considerably above this figure.

From the results obtained, several conclusions are evident in regards to the hydrogenation of Fort McMurray bitumen.

That hydrogenation of the larger part of the bitumen proceeds with ease and commences at comparatively low temperatures has been demonstrated. Further, the rate of hydrogenation is very dependent on the temperature, the presence of a catalyst, and the previous extent of hydrogenation. Reaction commences slowly at 200°C and increases in rate with rising temperature. The presence of molybdcic anhydride doubled, approximately, the rate of reaction. The extent and speed of hydrogenation decreases with successive treatments of the same lot of bitumen due to the adverse effect of an increasing proportion of simple hydrocarbons.

An increase in the relative amount of hydrogen to bitumen in the autoclave has the effect of increasing the absolute rate of reaction and the degree of hydrogenation possible in one treatment. In consequence of the shorter time required, coke formation is largely suppressed.

The optimum temperature for use in a static apparatus is not less than 425°C nor more than 450°C. Rapid hydrogenation and little coke formation occur in this temperature range.

Experiments on distillation residues from hydrogenated bitumen reveal the presence in this bitumen of a small and very stable asphaltic fraction. This material has not been hydrogenated without excessive coke formation, but the problem does not appear to be insoluble. It may be that a higher temperature will be necessary and as a consequence, two reaction chambers.

The occurrence of two co-existent equilibria has been assumed in an attempt to account for the course of the reactions in the autoclave. One reaction is between bitumen and hydrogen, and the products of hydrogenation. The other is between bitumen and gaseous hydrocarbons, and the products of cracking. An increasing temperature favours the latter reaction more than the former. Careful temperature control is essential in the prevention of coke formation through the second reaction.

The mechanism of the reaction of hydrogen with the bitumen would seem to consist of an addition of hydrogen to the unsaturated linkages produced by thermal decomposition of the complex carbonaceous materials.

Water Gas Reactions.

This work was carried out with the assistance of H. E. Morris.

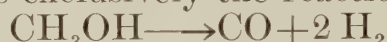
In a comprehensive survey of possible chemical processes that could utilize natural gases as raw material, the chemistry of water gas and like mixtures has an important part.

Carbon monoxide and hydrogen, or carbon dioxide and hydrogen, mixtures are readily and cheaply produced from the simple saturated hydrocarbons that make up natural gases. As is well known, these gas mixtures are reactive and may produce a variety of pro-

ducts with the help of suitable catalysts and suitable conditions of temperature and pressure.

There are two general methods of investigation of these reactions in order to test the suitability of different catalysts. The first method involves the passage of the gaseous mixtures over catalysts under pressure and the determination of the products and extent of any reactions. This method gives direct unequivocal information on the efficiency of the catalyst in promoting the desired reaction, but is rather cumbersome.

The second method, which was suggested by Patart, involves the decomposition of the desired product over the catalyst being tested and examination of the products of this reaction. The principle that a catalyst promotes both forward and reverse reactions in a chemical equilibrium is tacitly assumed. As an illustration, a catalyst that promotes exclusively the reaction



may be expected to promote, in some degree at least, the reverse reaction rather than other possible reactions. This method has been vigorously pursued by Frolich and co-workers, and is a general method of catalyst testing in vogue today. It has actually been shown experimentally that, with a reasonable degree of latitude, a catalyst which promotes the decomposition of methanol to carbon monoxide and hydrogen will also promote the formation of methanol from these gases under pressure. Both methods have been used in the work here reported, reactions being investigated in both directions with a variety of catalysts under different conditions. Such studies had as an objective, apart from contributing to the knowledge of catalysts, the possibilities of synthesis of ethyl alcohol by the hydrogenation of carbon oxides. Their practical relation to the basic problem, the chemical utilization of natural gas, is clearly evident upon consideration of the much larger market for ethyl alcohol than for methyl alcohol.

The catalytic decomposition of ethyl alcohol has been quite extensively investigated for several reasons. Due to the fact that it may undergo decomposition reactions involving either dehydration or dehydrogenation, it is a satisfactory compound for the determination of the specific nature of the activity of a catalyst. Similarly it is a most prolific source of information in investigations dealing with the mechanism of catalysis.

While the decomposition of alcohol with single metal catalysts, or with the addition of small quantities of promoters, has been rather thoroughly investigated, there is very little work reported on the action of binary mixtures of catalysts. The majority of the catalysts studied in this work are of this latter class.

Recent work on the mechanisms of catalytic reactions indicates that in many cases the reactants do not follow the most obvious routes to the final product; rather, the final products are the result of several consecutive reactions, and the factors influencing these reactions must be considered. Moreover, the existence of concurrent or side reactions frequently add to the complexity of the happenings over the catalyst. Some results on the decomposition of ethanol have shown that secondary reactions quite frequently occur leading

to the formation of a variety of products other than can be due to simple dehydrogenation or dehydration. From the results obtained in this study the conclusion has been reached that the catalytic decomposition of ethyl alcohol is a complex phenomenon in which the products of primary dehydrogenation or dehydration readily undergo a number of secondary reactions. The simple dehydration and dehydrogenation reactions have been observed, but the secondary formation of ethane, methane, carbon dioxide, and acidic condensates, previously noted by other investigators, has been confirmed and the reactions leading to these products have been more thoroughly examined.

The current theories of high pressure syntheses involve the assumption of many intermediate steps. It appears to be a reasonable conclusion that this work has further justified such a theory in view of the difficulties encountered in an effort to decompose alcohol to carbon monoxide and hydrogen. The reverse reaction, synthesis of ethyl alcohol from water gas or from carbon dioxide and hydrogen would appear to be possible only through one or more intermediate steps. The occurrence of a process of this nature on one catalyst is of a smaller order of probability than the comparatively simple reactions which lead to methanol.

The experiments at high pressures and temperatures have not yet yielded results worthy of much consideration. The leads given by the previous work on the decomposition of ethyl alcohol were not very definite and even the most promising catalysts do not produce appreciable quantities of compounds more complex than methanol. The work is incomplete and is going forward on other catalysts developed in the light of the results obtained.

At the present stage of this research it is difficult to draw any conclusions with regard to the results. The empirical nature of the methods of catalyst testing does not permit much speculation and involves a large amount of negative results. There does not appear to be any relation between the results of the decomposition of ethyl alcohol and the corresponding synthesis. With those catalysts and conditions utilized, two primary reactions occur, the production of methane and water or carbon dioxide, and the production of methanol.

No evidence of further reaction has been obtained other than a slight production of oil and of acetic or formic acid in a few cases. Amounts of oxygenated organic compounds of less than 1% or 2% would escape detection. The complex series of reactions outlined in the literature does not appear to occur to any great extent. Methyl ether has not been found in any quantity even with a definitely dehydrating catalyst; this is not in line with the experience of others.

It has been shown that carbon dioxide and hydrogen readily produce methanol on a suitable catalyst. This catalyst is also efficient in the production of methanol from carbon monoxide and hydrogen. This would suggest that there is a similarity between the two reactions involving probably in the first instance a primary reduction of carbon.

Pyrolysis of Natural Gas.

This work was carried out with the assistance of P. E. Gishler.

This division of the Natural Gas research made good progress during the year. The examination of Viking gas was nearly completed and work commenced with Turner Valley gas. All recent work has been confined to the production of maximum yields of solid and liquid hydrocarbons. Efforts to produce ethylene from natural gas have been discontinued as this subject is being examined in the National Research Council laboratories at Ottawa.

Methods of collection of the products of the reaction have been developed which are analogous to commercial methods and are very satisfactory. The standard method consists of a settling chamber to collect the bulk of the tar and naphthalene, an electrical precipitator to remove the tar mist, and activated carbon as an absorbent for the vapors of volatile materials. The activated carbon may be replaced by silica gel or by an absorption oil with a small loss in efficiency. The use of an absorbent such as carbon may introduce some uncertainty into the exact determination of yields in small scale work since it will absorb gases as well as vapours in appreciable amounts. These absorbed gases are later displaced by vapors absorbed preferentially by the carbon. Thus, the measurement of yields by weight increase of activated carbon may be of doubtful value and this is particularly true in short experiments. Two means of minimizing this error exist: first, by the use of comparatively large quantities of gas, and second, by the use of the same carbon in a series of experiments run in succession. In this manner, the yields of oil as given by weight increase of the carbon have been found to agree closely with the yield as found by recovering the absorbed oil from the carbon.

Considerable attention has been given to two points in the experiments, namely, the real temperature of the gas undergoing pyrolysis and the time during which the gas is at this temperature. The exact determination of these quantities presents serious difficulties which have not been satisfactorily solved. However, these quantities are known with sufficient accuracy and conditions may be reproduced satisfactorily for comparative and practical purposes. Their absolute values are chiefly of theoretical interest as long as the relative conditions between experiments are known.

A variety of reaction tubes have been used, differing both in shape and size and in material. It may be said that the geometry of the tube, although of some importance, has small influence when compared to the effect of changing temperature and time of contact. The point is worth further investigation as offering promise of higher yields. The material from which the reaction tube is made has no apparent influence so long as it is capable of acquiring a deposit of graphitic carbon. It appears to be an essential condition for successful operation that the reaction space be enclosed entirely by a hard scale-like variety of graphite. Metal tubes are inferior to refractory tubes in that they do not readily form such carbon from natural gas. The use of inert gaseous sheaths of nitrogen between the natural gas undergoing pyrolysis and the tube wall has been examined with interesting but inconclusive results.

These experiments indicated possibilities of large yields and require further work.

Most of the laboratory work has been carried out with fused quartz tubes. These tubes are most satisfactory, and have an indefinitely long life under the severe conditions of the process. As an illustration of the nature of the results obtained, Table XV is presented. The essential data of a few experiments have been taken from a large number of similar experiments.

The temperatures tabled are relatively correct only. It is certain that the true temperature of the gas is approximately 30°C below the tabled values. The time in the furnace does not give the time of contact of the gas with the hot part of the tube. It is very probable that the time of contact is not more than one-tenth the figures tabled. The relative values of the time of contact, however, will be the same as the relative values of the time in the furnace.

The column headed "expansion" gives the percentage increase in volume of the exit gases referred to the natural gas supplied. The "unsaturateds" gives the sum of all those gases such as acetylene and ethylene in the exit gases. The yields refer to gas volumes measured at 700 mm. Hg. pressure and 22°C.

TABLE XV.—PYROLYSIS OF NATURAL GAS

No.	Temp. °C	Flow cc./min.	Time in fur- nace seconds	Expan- sion %	Exit Gas			Yield Gals./1000 cu. ft.
					Unsat- urateds %	Hydro- gen %	Methane %	
Viking Gas								
143	950	155	14.6	8.5	2.9	16.6	73.6	0.33
145	950	225	10.0	8.5	3.2	12.9	73.8	0.26
149	1000	420	5.4	10.3	3.2	18.6	71.5	0.36
150	1000	260	8.7	11.5	2.7	20.4	70.2	0.43
153	1050	650	4.5	12.0	3.7	25.7	63.6	0.37
155	1050	420	5.4	14.2	3.1	20.0	.....	0.45
159	1100	853	2.65	13.6	3.6	24.5	64.2	0.40
Turney Valley Gas								
a	950	158	10.9	23.8	5.6	23.8	66.0	0.60
d	1000	364	4.7	25.0	7.0	25.0	63.5	0.64
e	1050	490	3.5	27.4	5.3	33.2	56.6	0.70

Summarizing the results in regard to oil yield, a single treatment of Viking gas can yield 0.43 gallons of oil per 1000 cu. ft. of gas. Of this, 0.22 gallons is light oil and 0.21 gallons tar. Turner Valley gas will yield 0.66 gallons of oil, of which 0.36 gallons are light oil. These represent approximately a 12% yield from Viking gas and a 17% yield from Turner Valley gas on the basis of available carbon. Some 25 %of the entering natural gas is decomposed in one way or another. The production of light oil may be increased somewhat above the figures quoted at the expense of the tar fractions. The total yield is, however, decreased as the drop in tar production is greater than the increase in light oil production. The efficiency of the process, based on natural gas decomposed, is increased. A step-wise process involving successive treatments of the same gas is indicated and will be investigated.

The light oil is of a pale yellow color and is largely benzene. Fractional distillation gave the following data:

Initial B.P.	75°C
81 % over	80.5°C
91.4 % over	112°C
93.4 % over	150°C
6.6 % residue (naphthalene)	

The tar consists largely of high boiling aromatic hydrocarbons such as occur in coal tar. Fractional distillation gave the following data:

Initial B.P.	79°C
3.5 % over	210°C
17.5 % over	235°C
31.6 % over	290°C
44 % over	345°C

Napthalene, anthracene, chrysogene, chrysene and diphenyl methane have been identified as constituents of the tar.

ELECTRICITY ON THE FARM

BY H. J. MACLEOD

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The object of this research is to obtain the necessary information which will enable the Council to recommend the most economical type of electric power supply for farms in different localities and under various local conditions.

The first step was to determine the number of electrified farms already in the Province and their present power requirements. Farms supplied by windmill electric and Delco installations do not in general keep any records of the amount of power used. But the records of farms connected with the Calgary Power Company's system are quite complete. The following statement from the Company's records shows the development during 1929. The year is divided into four periods of three months each.

TABLE XVI
STATEMENT FROM CALGARY POWER COMPANY'S RECORDS, 1929

Quarter ending	No. of Consumers	Total kw. hrs.	Kw. hrs. per month per consumer	Average price per kw. hr.
March 31	117	19,393	55.3	11.6
June 30	145	16,738	38.3	16.3
September 30	190	25,139	44.0	19.9
December 31	200	33,794	56.3	11.5

It will be noted that the number of consumers practically doubled in the year, but the average consumption is very low. In the majority of cases it represents a lighting load with perhaps an electric washer, iron and toaster.

For comparison the statements of the two test farms selected in consultation with the U.F.W.A. are as follows:

Farm A—Equipped with lighting, electric range, water heater, pump, 5 H.P. chopping mill motor, washing machine, ironer and toaster, used on the average 492 kw. hrs. per month for a period of 19 months. This is over ten times the amount of power used by the average farm.

Farm B—Equipped with lighting, electric range, refrigerator and pump motor, used an average of 228 kw. hrs. per month during 1929—four and one-half times that of the average farm.

On these two farms the cost per kw. hr. was approximately six cents—less than half the average cost in the statement above.

When the figures for 1930 are received a detailed study of the cost for certain definite loads per month will be made. In the meantime the following observations may be noted:

1. In the majority of cases the amount of power used scarcely justifies the installation, from an economical point of view, for either the farmer or the company.

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